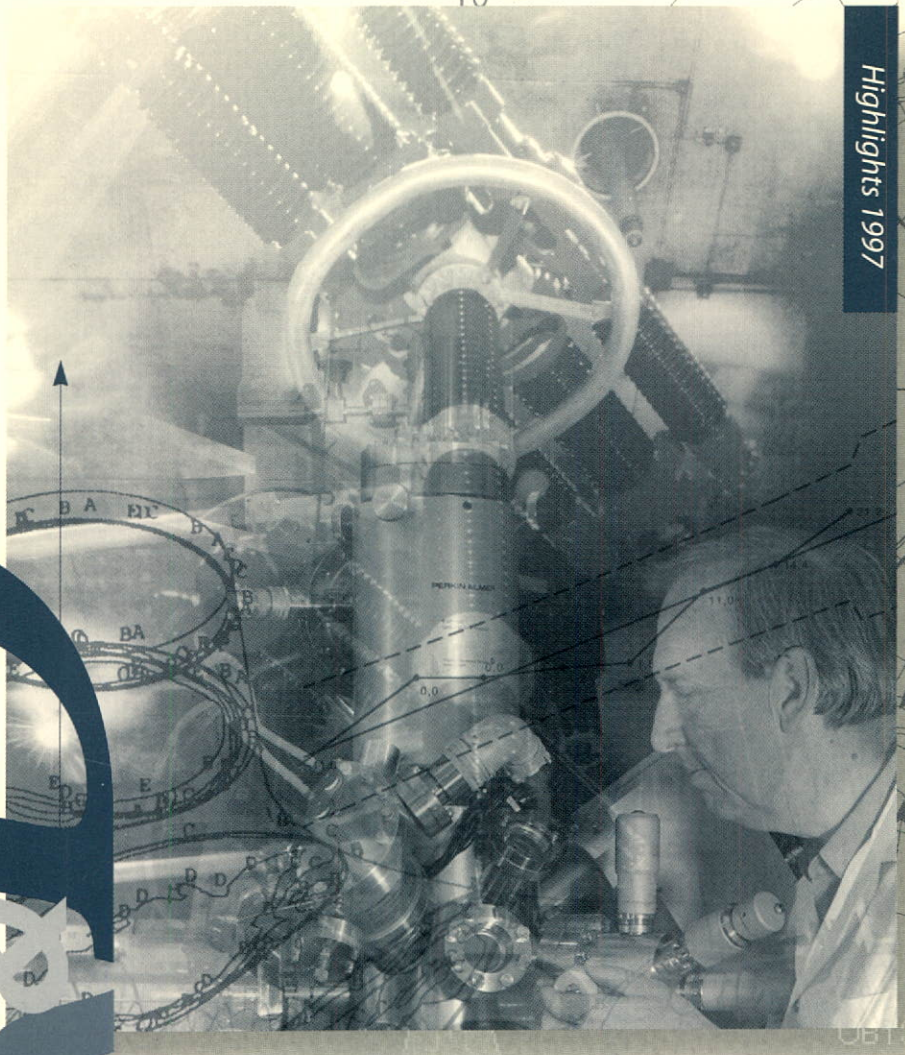
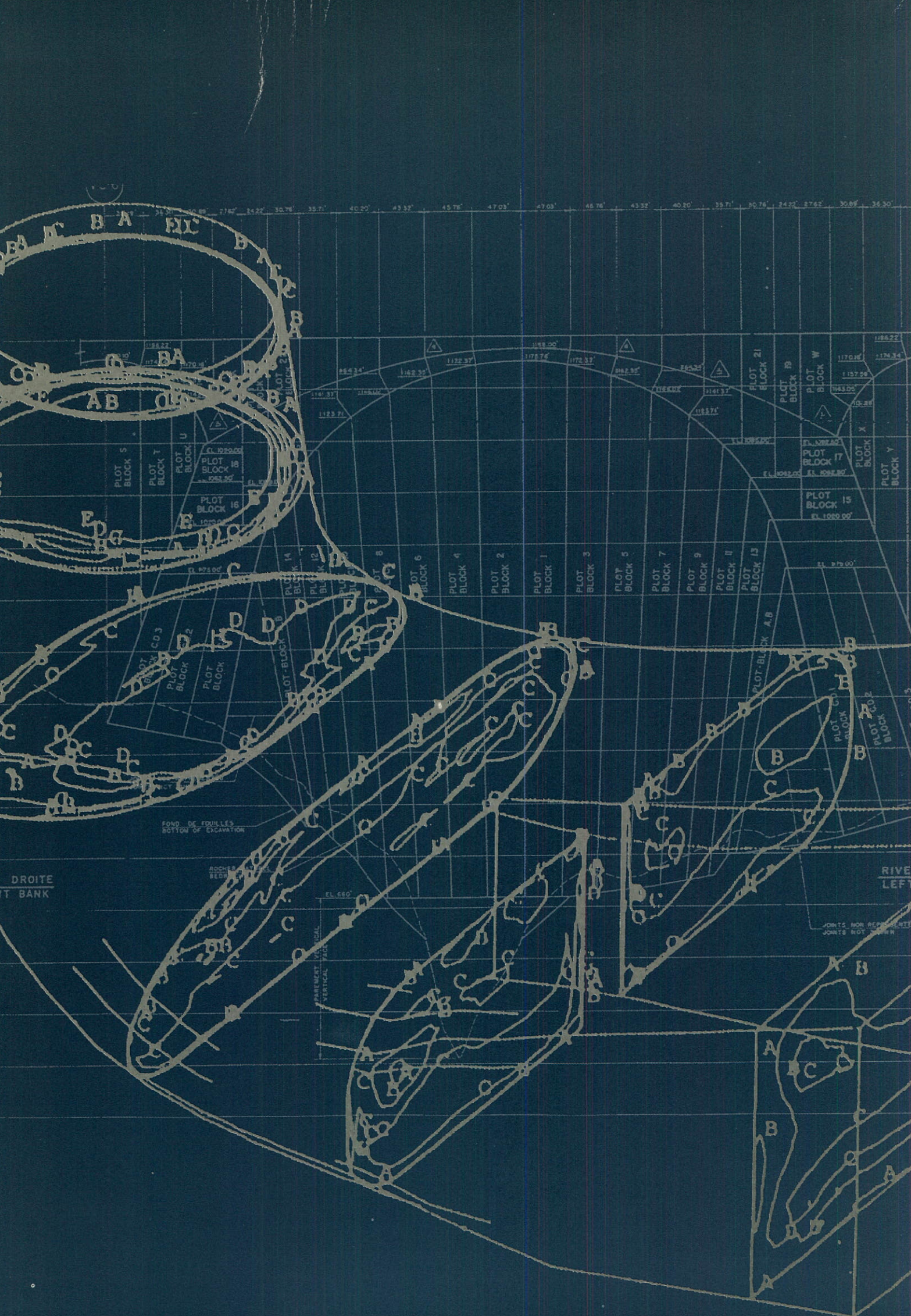
Hydro Québec

Research and Development



Highlights 1997

R&D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Over the past year, Hydro-Québec invested $118 million in research and development, broken down as follows: generation –$13M; transmission – $22M; distribution – $11M; utilization of energy –$12M. The utility also invested $10 million in long-term research projects and $6 million in prospecting projects. Added to these expenses are other investments and expenses of $26 million, as well as activities related to outside contracts totalling $18 million from our major clients: Atomic Energy of Canada Ltd., ABB, Teqsim, Lithos, NKT câbles, Alcatel, BASF, Prolab and GE Hydro.

The funds required to carry out these activities were provided by the utility's business units in charge of generation ($10.9M), transmission ($7.8M), distribution ($6.1M), utilization ($8.1M), commercialization of technology ($24.3M), as well as from other units ($1.1M). This $58.3-million amount, added to the $18 million in revenue from outside sources and the utility's contribution of $41.4 million, totals the $118 million earmarked for R&D.

Of the above amount, $90 M went to the **direction principale Recherche et Développement.** *An amount of $1M goes towards determining R&D needs, $10M to prospecting projects, $16.8M to long-term projects, $27M to research activities, $15M to testing, and $3.3M to development-related work. Finally, $16.9M is used to defray the cost of R&D support activities. A total of 722 research scientists, specialists and support and management staff were involved in these various activities in 1997.*

Using a client-supplier approach, the **direction principale Recherche et Développement** *obtains its in-house funding from the business units. Totalling $30.6 million, this revenue is broken down as follows:* **direction principale Commercialisation de la technologie et Participations** *– $8.8M;* **unité Distribution** *– $5.3M;* **division TransÉnergie** *– $4.3M;* **groupe Production** *– $3.6M;* **groupe Projets et Affaires internationales** *– $3.3M;* **groupe Services énergétiques** *– $1.5 M;* **unité Clientèle d'affaires** *– $1.9M;* **unité Clientèle régulière** *– $1.0M;* **unité Services à la clientèle** *– $400,000;* **various business units** *– $500,000.*

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Introduction

The technological leadership demonstrated by Hydro-Québec is a function of the R&D efforts expended over the last thirty years. And we believe that Hydro-Québec has maintained its top-ranking position by targetting the results of its R&D activities according to the actual needs of its business units, clients, and markets.

In fact, not only will R&D better meet the utility's needs, it will also show that it is capable of adapting to the new conditions created by the opening up of markets by helping to reduce maintenance costs, increase equipment availability, optimize energy reserve management, and increase the capacity and flexibility of the transmission system.

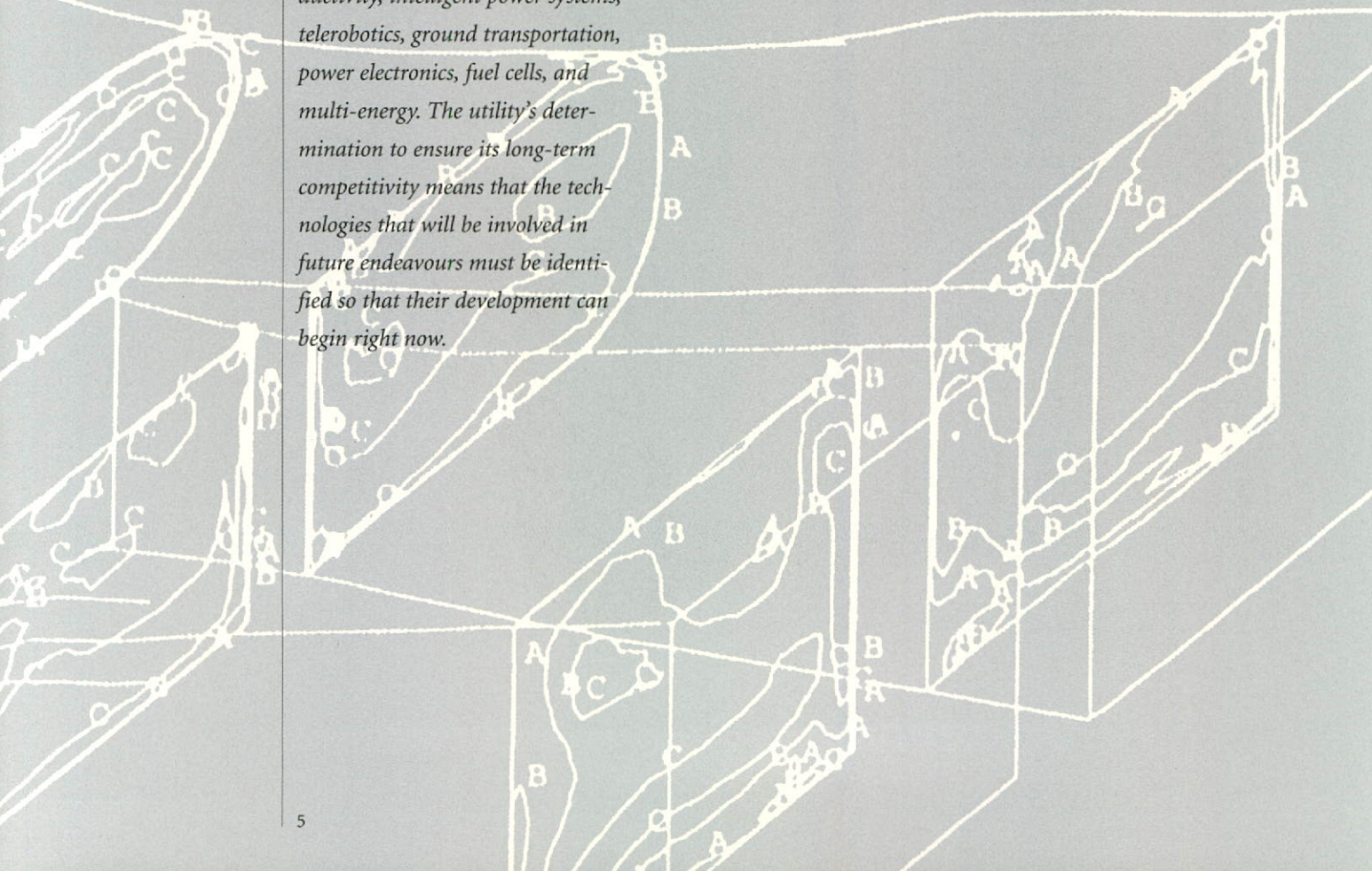
The direction principale Recherche et Développement, *jointly with Hydro-Québec's technological units, has thus drawn up technology-related policies which Hydro-Québec intends to implement by the year 2002 in order to consolidate its growth and increase its profitability. Taking into account the radical changes affecting electric utilities, the resulting master plan presents numerous opportunities for realizing a new R&D vision through a greater input from our scientific personnel in terms of know-how and innovation. The resulting profitability paves the way for expanded use of our international-calibre test facilities.*

In all likelihood, Hydro-Québec will not be able to maintain its world leadership in hydroelectric generation and transmission or position itself on the domestic and international markets without continuing to develop advanced technology. Our business units' revenues grow through technological innovation. Integrating new technologies with our basic activities and applying the latest scientific

breakthroughs in the electrical power industry all contribute to the ongoing process which is being implemented within a context of growth and profitability, for ourselves as well as for our clients and business partners. The same goes for our determination to take this opportunity to reduce the costs and risks associated with R&D projects and to maximize their economic spinoffs by focusing on business partnerships.

Hydro-Québec is also aware that fulfilling its needs through R&D is contingent on a future vision. This is why the utility has also asked those in charge of R&D to carry out prospecting and long-term research in areas such as superconductivity, intelligent power systems, telerobotics, ground transportation, power electronics, fuel cells, and multi-energy. The utility's determination to ensure its long-term competitivity means that the technologies that will be involved in future endeavours must be identified so that their development can begin right now.

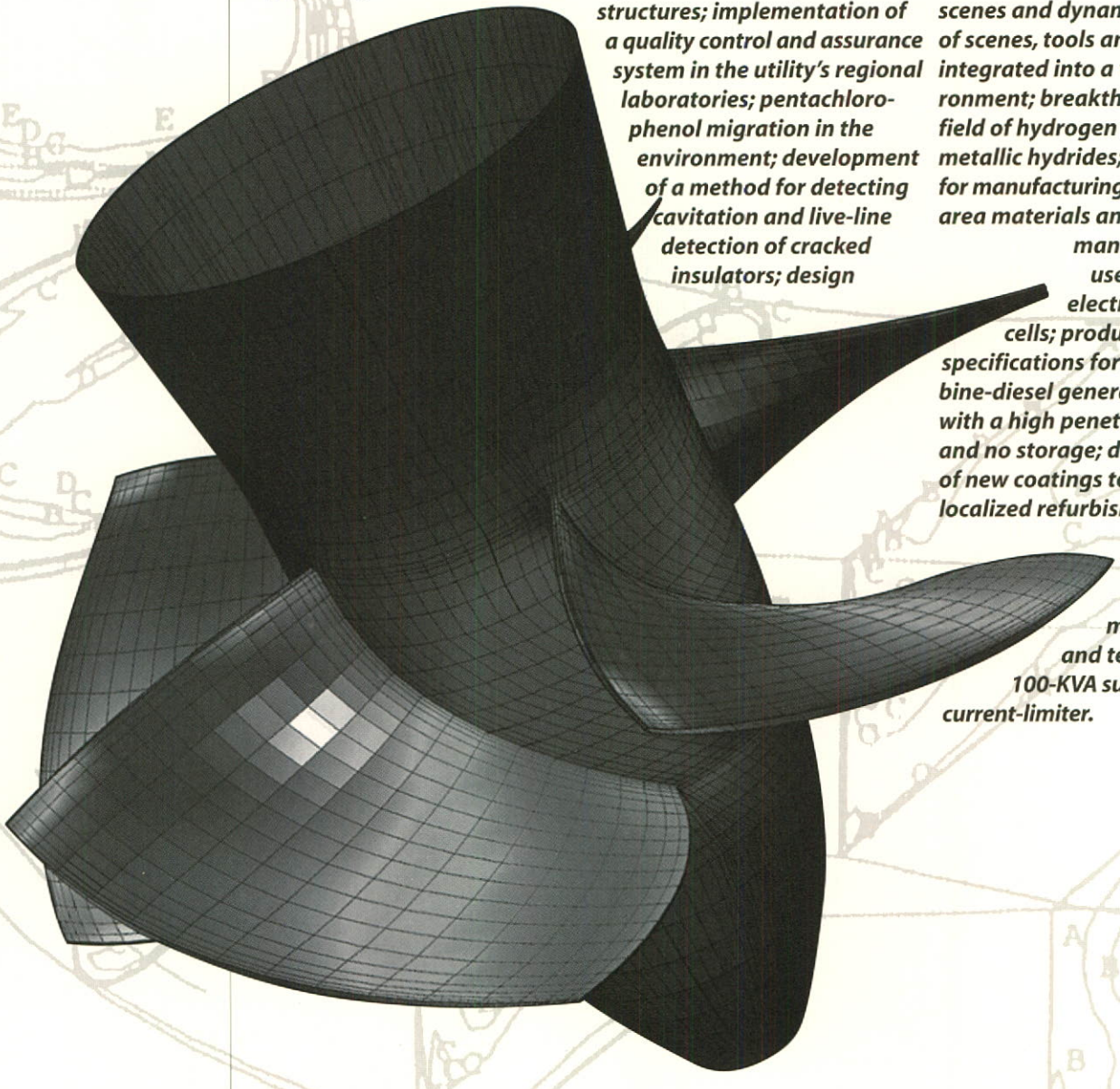
Joining forces with the best in order to compete with the best: this has always been the principle underlying our system of values. We not only intend to pursue this course, but to also step up our efforts in this area by making use of the expertise available outside of Hydro-Québec, in universities, other research centres and industry. This opening up will translate into joint ventures in the development and marketing of technological products. Our efforts will therefore be geared towards maximizing the return on our R&D investments by capitalizing on the technological know-how acquired over the past 30 years.



Generation
Technology

Hydro-Québec has acquired an international reputation through the implementation of innovative hydroelectric generation technologies. Within the generation technologies unit* (unité Technologies de production), *a team of researchers and technicians specialized in civil engineering structures, materials, the environment, chemistry, generation equipment, mechanical engineering, robotics and emerging technologies is working on a daily basis to help the utility maintain its international leadership.

Once again, the past year's results bear witness to considerable interest in their work, as shown by the following list of achievements: development of products, methods and equipment for concrete injection and crack repair; characterization of protective coatings for steel structures; implementation of a quality control and assurance system in the utility's regional laboratories; pentachlorophenol migration in the environment; development of a method for detecting cavitation and live-line detection of cracked insulators; design of hydraulic turbine analysis models; identification of the dangers caused by end-arm discharges in stator windings; development of a robot for inspecting the mechanical supports in the primary heat transport system of Gentilly-2 nuclear generating station, a robot for cleaning transmission lines, and a robot for inspecting underground installations and substations; formulation of 3D modelling methods for actual scenes and dynamic modelling of scenes, tools and processes integrated into a virtual environment; breakthrough in the field of hydrogen storage in metallic hydrides; new process for manufacturing high-specific-area materials and high-performance catalysts used in polymer-electrolyte fuel cells; production of the specifications for a wind turbine-diesel generator system with a high penetration level and no storage; development of new coatings to facilitate localized refurbishing of surfaces; and, lastly, the manufacturing and testing of a 100-KVA superconducting current-limiter.



Civil Engineering Structures and Materials

Dam repair

We pursued our research at IREQ on the development of injection products, methods and equipment by injecting large slabs of concrete. In 1998 we will take part in the injection of arch 5-6 of the Daniel-Johnson dam, as the advisory committee on dam safety has lifted the injection moratorium that had been passed in 1984. Regarding the products, we selected four of the 60 waterproofers tested for application at four points of the Beauharnois dam. Although the test results were not conclusive, the waterproofers proved to be highly effective on bridge pillars. It should be noted that we are completing the summary version of our report on membranes for submission to the geomembrane committee of the International Commission on Large Dams.

As part of our repair work on the downstream faces of dams, we conducted a study on the performance of various pretested configurations of thermal protection systems. The study revealed that two systems, those combining air gap and concrete, as well as air gap, synthetic insulation and concrete, appeared to have excellent potential for field application. We also made headway in the development of shotcrete mixtures with high concentrations of fly ash. When subjected to durability, carbonation and corrosion tests, these mixtures performed very well compared to concrete without any pozzolanic materials. Other studies, for which the results and ultrasonic data have been compiled, dealt with concrete expansion potential at the La Tuque and Trenche dams in relation to alcali-aggregate reactions. Expansion tests then allowed us to validate the effects of Lithium and other chemical or mineral additives on resistance to these same reactions, as different non-reactive concrete mixtures were finally tested at the lac Mitis installations.

Tested at the Carillon dam, the "*impact-écho*" method developed at IREQ's test bench was capable of detecting cracks and irregularities in the concrete to a depth of 12 m. Moreover, the analysis of the six products we had recommended for repairing faults caused by cavitation and corrosion in concrete surfaces confirmed their effectiveness after five years of use.

During the past year, we collaborated with the Generation group on a project carried out at the Rapides-des-Quinze, La Croix, Carillon and La Gabelle dams. We were also asked to carry out a research and development project on sulfation and completed our investigation on scale formation in the concrete of gate heated steel elements observed on certain pillars of the Témiscouata dam.

Scompi robot

At the request of users, we made several improvements to the Scompi robot software. Scompi is a compact robot with a simple program which can work on surfaces with complex configurations, developed by IREQ for the in-situ repair of damage from cavitation in hydraulic turbines. A program is now used to select the welding wire, the type of grinder and the configuration, while several commands have been transferred to the pendant to minimize operator movement.

Material failure and degradation

We characterized the performance of 15 protective coatings for steel structures for which properties such as bonding and resistance to abrasion, corrosion and cavitation were assessed. A few systems installed at Manic 5 PA should be inspected in the summer of 1998.

Early in the year, we will also produce a selection guide summarizing the results of the project, which showed that Ciba 8510 and 8526 coatings are among the most resistant to cavitation. They will be used in the near future for a related project regarding the smoothing of hydraulic passages of Farmer generating station and the assessment of gains in output.

Moreover, a project on the mechanical and metallurgical characterization of pressure tubes made of Zr-2.5% Nb alloy at Gentilly-2 generating station was also carried out. The project basically consisted in collecting all of the results of the J_{IC} durability tests, impact tests and metallographic analyses obtained by scanning electron microscope in order to obtain a correlation between the mechanical properties (especially regarding impact resistance) and the other characteristics of the tube material. The results will be used in making decisions regarding the retubing of Gentilly-2 generating station, for which the project team also undertook to study the creep degradation mechanism for the same pressure tubes, with a literature review on the subject being proposed to the client.

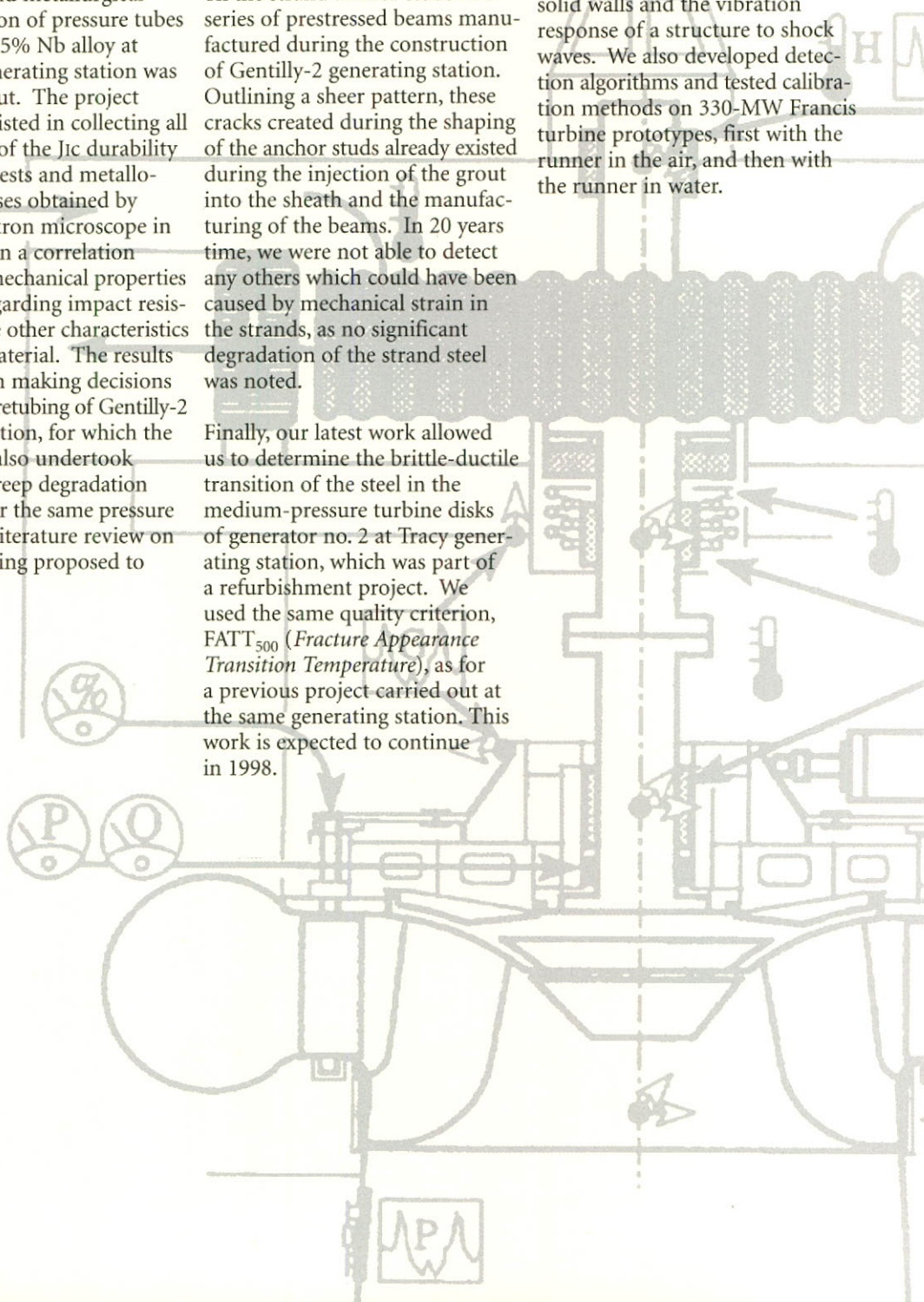
We also provided several metallurgical and mechanical assessments during the annual shutdown of Gentilly-2. Two other major studies were carried out for the generating station, one on the residual fatigue life of the bypass steam pipes, and the other on the problem observed with the Q19 steel tube. We also did a metallurgical evaluation of the 20-year-old prestressed beam. Microstructural analyses in fact revealed cracks on the strand anchor studs in a series of prestressed beams manufactured during the construction of Gentilly-2 generating station. Outlining a sheer pattern, these cracks created during the shaping of the anchor studs already existed during the injection of the grout into the sheath and the manufacturing of the beams. In 20 years time, we were not able to detect any others which could have been caused by mechanical strain in the strands, as no significant degradation of the strand steel was noted.

Finally, our latest work allowed us to determine the brittle-ductile transition of the steel in the medium-pressure turbine disks of generator no. 2 at Tracy generating station, which was part of a refurbishment project. We used the same quality criterion, $FATT_{500}$ (*Fracture Appearance Transition Temperature*), as for a previous project carried out at the same generating station. This work is expected to continue in 1998.

Generating Equipment and Mechanical Engineering

Method for detecting cavitation

At the request of the *direction Expertise et Support technique en production*, we devised a method for detecting cavitation in hydraulic turbines based on two factors: characterization of vapour cavity implosion near solid walls and the vibration response of a structure to shock waves. We also developed detection algorithms and tested calibration methods on 330-MW Francis turbine prototypes, first with the runner in the air, and then with the runner in water.



This method was integrated into a complete cavitation detection and follow-up system, which includes an optimized sensor, calibration source and conditioner. Running on an industrial PC, the system's central processing unit is comprised of the following modules: data acquisition, calibration, processing, materials, output and interface with the SUPER continuous monitoring system for turbine-generators. The system is also capable of adapting to generating stations which do not have SUPER; in addition, its cost was reduced through the use of industrial parts. To date, the method has been used to carry out a comparative analysis of cavitation found in two Francis turbines as part of a project requested by Alcan, as well as for the commissioning of a new Kaplan turbine at La Gabelle generating station.

Live-line detection of cracked insulators

For two years we have been working on developing a prototype of a live-line system for detecting cracked insulators in order to make up for the inadequacies of visual inspection. We completed the validation phase and began developing the prototype, which will make use of the vibro-acoustic signature of each insulator porcelain disk. Two major challenges remain: to find an algorithm capable of detecting cracks without error or prior knowledge of the healthy signature, and to mechanically or acoustically excite the porcelain and measure its vibration while complying with the required clearances.

Hydraulic turbine analysis models

Phase III of the MATH project ("*Modèles d'analyse des turbines hydrauliques*" – Hydraulic turbine analysis models) continued last year with the numerical analysis of the dynamic behaviour of generating units at LG-1 generating station and of the problem arising from the inadequate output of LG-3 hydraulic turbines. In the first case, simulation of the fluid flow in the turbine's admission duct was used to attribute the scope of the operating range to a phenomenon whereby water is recirculated near the hub. The flow calculations were also used to determine the pressure in the runner, whereas measurements made in the field using SEET served to validate the pressure at the end of the blades. The pressure data were then used to study the dynamic behaviour of the shroud. The analysis results confirmed the turbine's design and operational safety, even though statistically high stresses were measured at the base of the blades. A dynamic study is currently being carried out to examine the possibility of cracking at this location.

In the case of LG-3, detailed flow simulation in all the component parts explained the less-than-optimal turbine output, i.e. the low interaction between the blades and the draft tube. Until now, the answer to this problem had never been found. Work will continue in 1998 with a view to developing the adjustments to be made on a reference turbine.

Guide for assessing generating units

The *direction Expertise et Support technique en production* also asked IREQ to produce an initial guide on the diagnosis of generating units which assembles some of the utility's knowledge in this area. Subsequent editions will focus on the regional units and will reflect changing needs. Brimming with explanations, figures, diagnostic rules and tables, the guide is presented in the form of a diagnostic tree referring the user to a number of technical data sheets and case studies. The guide is intended to improve and standardize diagnostic techniques for purposes of preventive maintenance. It will also result in efficient use of the SUPER system and highlights the know-how of personnel from the various technical units.

End-arm discharge in stator windings

We also undertook a study on the danger presented by end-arm discharges in stator windings. This project was initiated as a result of the substantial use of stress-grading paints on the stator end arms. These paints are designed to control the electric field but their properties are such that they interrupt the effect of partial discharges (PDs) in the end arms, which can over time reduce generator service life. As a first step, we assessed the actual dangers of the various effects of the PDs, then drew up a procedure for extending the lifespan of the windings. As Hydro-Québec owns a large number of generators of varied size, it is crucial that stator windings be kept in good condition in order to ensure service continuity.

Environment and Chemistry

Quality control and quality assurance in Hydro-Québec's regional laboratories

We have successfully completed the three-year project requested by the *unité Expertises et Support technique appareillage de transport*, TransÉnergie division, with a view to setting up a quality assurance and quality control program in Hydro-Québec's regional laboratories. The two oil analysis laboratories part of the *unité Laboratoires et Huiles* wished to obtain ISO/IEC Guide 25 accreditation in 1998. As a first step, we prepared training sessions on laboratory practices, statistics, control charts and method validation. Then, in conjunction with technical personnel, we revised all of the analysis methods in order to bring them in line with recognized standards and integrate quality control. Special attention was given to a new method for analyzing dissolved gases which incorporates problem-solving processes.

Concurrently, we worked with the above unit on obtaining accreditation for its laboratories from the *ministère de l'Environnement et de la Faune* (Québec environment and wildlife ministry) for the analysis of PCBs in insulating oils. We also produced an internal document which outlines a general methodology which complies with all of the utility's standards and which defines the guidelines for drafting analytical procedures. Overall, the project allowed us to determine which improvements would be made to the quality control tools used for testing acidity, surface tension, the tangent delta and dielectric strength. In 1998 we will propose avenues of research in this area, and we will continue to provide the laboratories with the technical and scientific support they need to obtain accreditation.

Migration of PCP into the environment

To extend the service life of wood poles used in Hydro-Québec's transmission and distribution system, the utility subjects them to a pressurized treatment which involves injecting PCP, a preservative, first dissolved in oil in accordance with CSA standard O80.31-M1989. The treated poles thus contain a substantial amount of a PCP-oil mixture which may seep out into the environment.

At the request of the *Direction principale Environnement et Communications (DPCE)*, we attempted to determine how this migration occurred. We first studied the distribution of PCP and oil inside the poles. This study revealed a maximum concentration of the mixture on the pole surface and, according to manufacturers, variations of up to twice the volume of oil for comparable amounts of PCP. Thus, between the sampling points along a given pole, concentrations would vary by up to 20%.

The poles were then subjected to accelerated ageing tests designed by IREQ researchers to assess the quantity of PCP and oil leaking from the base and surface of the poles in order to determine whether pole length had an effect on the amount of seepage and how much the products are leached by rain. The test results revealed that PCP contained in oil leaks mostly from the pole surface and, to a lesser extent, through the base of the pole. Larger amounts were collected at the base of the pole depending on the length of the pole, owing to accumulated hydrostatic pressure. Leaching, however, proved to be negligible due to the hydrophobic properties of oil.

Once the average and extreme concentrations of the PCP-oil mixture migrating into the environment had been established, we integrated them into a mathematical model developed by the DPCE and designed to predict pole behaviour in a given environment. This work allowed us to calibrate the mathematical model, which had recently been put on the market. Lastly, it should be mentioned that the model was used to revise the siting criteria for PCP-treated poles near sensitive elements (e.g. bodies of water, wells, water table, ditches or areas frequented by children) and to reduce the required perimeter of protection.

Robotics

Prototypes of inspection and maintenance robots

Several robot prototypes were developed this past year for purposes of inspection and maintenance. The first one is used to inspect mechanical supports in the primary heat transport system during planned shutdowns shutdowns of Gentilly-2 nuclear generating station. It has five degrees of freedom and includes a probe on which several cameras are mounted. During three inspection programs, it reduced the dose of radiation to which power plant personnel is exposed by a factor of 10 thanks to a remote piloting station and the ease with which it is installed. It also provided visual information impossible to obtain by conventional means. In 1998, an updated version of the robot, with improved accessibility and remote-control functions as well as new sensors for angle and displacement measurements, will be developed. Steps are already being taken to implement the robot at other nuclear generating stations.

We were commissioned by the firm Etecen in Peru to develop a robotized brush for cleaning transmission lines. Following field tests, we delivered a prototype which Etecen found satisfactory and for which we expect to develop a standalone motorized version in 1998. Meanwhile, the United States Bureau of Reclamation chose our underwater robot for the inspection of the Pueblo dam in Colorado. This robot integrates advanced technologies such as a position-determining and position-control system, sonar, a laser camera, and a virtual environment which considerably facilitates large-scale inspections. The upgraded version to be developed in 1998 should be used for several inspection programs.

We also conclusively tested "Robin," a mobile inspection robot for underground facilities and substations. From an outside piloting station, Robin can determine the safety of even a large and crowded work area thanks to sensors used for color visual display, thermographic surveys, and the detection of dangerous gases and partial discharges. Our work also led to the industrialization of a robot for inspecting stator wedging, which provides a quantitative measurement of the wedging and can be inserted into the air gap without being disassembled. Two prototypes will be completed in early 1998 for site operation. Lastly, we created a new version of Gyrocam. Equipped with two colour cameras and coupled with a gyroscope, the Gyrocam system is linked to a 3D software program capable of detecting cracks in concrete structures and interpreting them with considerable precision.

Telerobotics

On the telerobotics side, we developed "Microb," a standard programmable software program. Equipped with a sequential and dynamic module and a real-time code generator, this software with high commercial potential could be sold as a specialized toolbox.

Partnerships

In closing, let us mention two partnership agreements which gave rise to two major projects. Lasting three years, the first project brings together Université Laval, the NRC and the firm Innovmétric, which will work on developing three-dimensional modelling methods of actual scenes. The second project, part of the third phase of the IRIS network of excellence, groups McGill, Western Ontario and Victoria universities, Université Laval, CRIM, the Canadian Space Agency, and three manufacturing firms. The aim of the project is to facilitate the execution of complex tasks through the geometric description and dynamic modelling of scenes, tools and processes integrated into a virtual environment. The two partnerships will require investments totalling $4.8 million over the next four years.

Emerging Technologies

In 1997, the direction principale Recherche et Développement *set up a unit charged with ensuring Hydro-Québec's presence in niches which are crucial to the future development of the utility and the energy industry as a whole. Our research focused on emerging technologies related to the generation, transmission and distribution of electricity and touching upon areas as varied as fuel cells, hydrogen storage, wind energy, advanced materials, superconductivity and* SF_6 *insulation.*

Hydrogen

A major breakthrough in the area of hydrogen storage in metallic hydrides led to the signing of two partnership agreements, one with German firms, and the other with several Québec partners. The discovery involves two facets: storage capacity and absorption and desorption kinetics. It led to two patent applications and the startup of a consortium project.

Fuel cells

Another patent application has been filed for a new procedure for manufacturing high-specific-area materials and high-performance catalysts used to make polymer-electrolyte fuel cells. In addition, Canmet's research contract, which deals with perovskite-based cathode materials for use in high-temperature fuel cells, was renewed. One of these cells has already been used to verify our synthesized materials. The École Polytechnique de Montréal and the Laboratoire de réactivité des solides in Dijon, France have continued their joint research project, and an agreement on the exchange of know-how in the area of SOFCs (Solid Oxide Fuel Cells) is currently being negotiated with Gaz de France.

Wind energy

In the area of wind energy, we have been actively involved in an executive committee mandated to draw up a strategy over the short, medium and long term. We also produced specifications for a wind turbine-diesel generator system with a high penetration level and no storage, developed a microprocessor with adaptive control and operated a wind turbine-diesel system for 120 hours in automatic mode at the Prince Edward Island test site.

New coatings

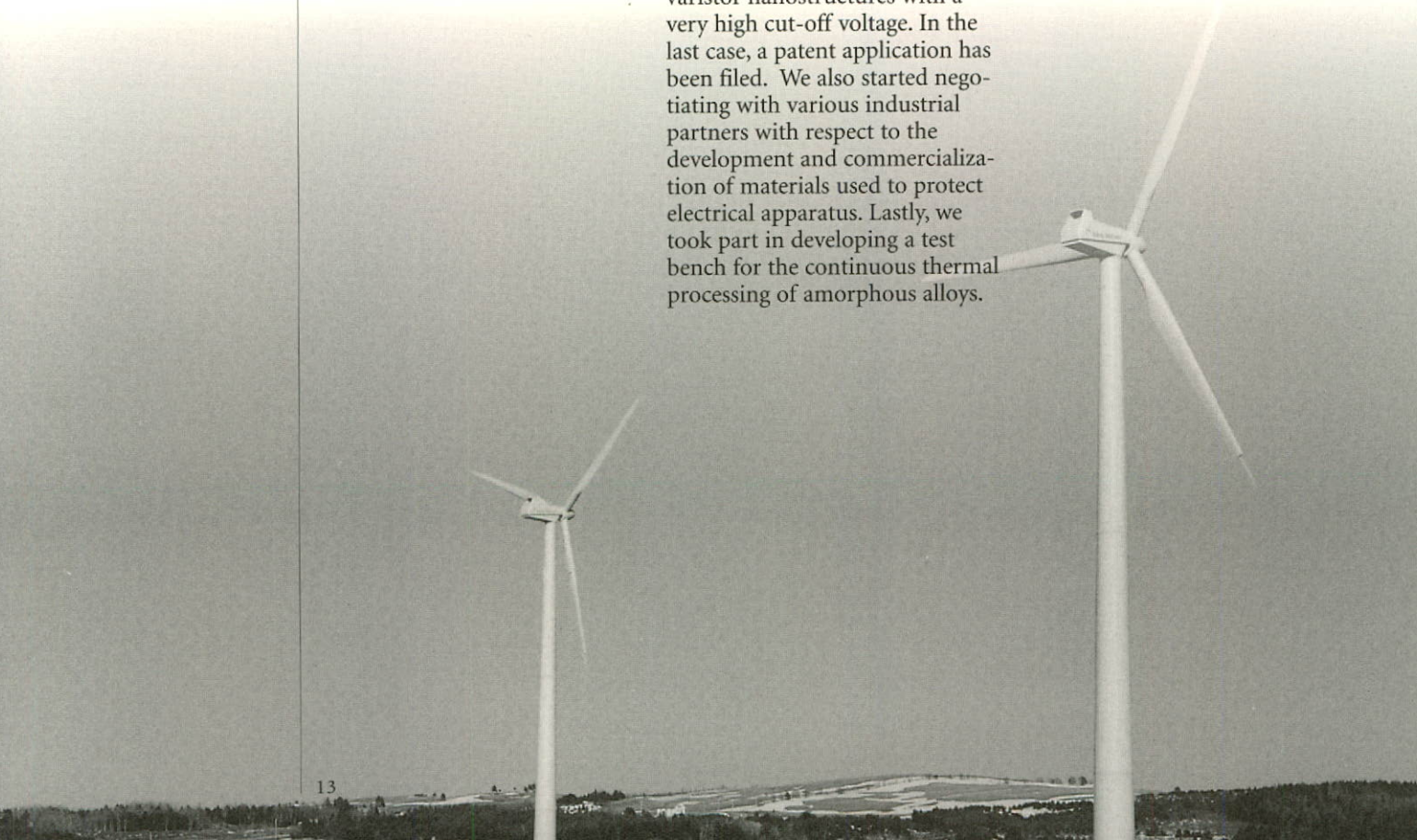
Our research in transmission and distribution led to the development of new Cu-W coatings based on the vacuum plasma technique, which could facilitate localized refurbishing of surfaces and the production of concentration gradients by thickness. We also made headway in the development of electroforming techniques for Fe-Ni alloys with a high iron content, the manufacture of parts in pure iron for magnetic applications, and the development of varistor nanostructures with a very high cut-off voltage. In the last case, a patent application has been filed. We also started negotiating with various industrial partners with respect to the development and commercialization of materials used to protect electrical apparatus. Lastly, we took part in developing a test bench for the continuous thermal processing of amorphous alloys.

Superconductivity

In the area of superconductivity, our activities have focused on the design, manufacture and testing of a 100-KVA superconducting current limiter – carried out jointly with our partner, Siemens – as well as on the development and characterization of wires and plates made of superconducting material for electrochemical application.

SF_6

Other research centered on the evaluation of absorbing materials used in SF_6 equipment. We established a few diagnoses, especially regarding direct sampling of gas, and studied some of the most commonly used contaminants in the field. We also studied phenomena pertaining to the dielectric recovery of SF_6, including transition of the conductive state to the insulating state after arc interruption, and designed an experimental approach for simulating the dielectric recovery.



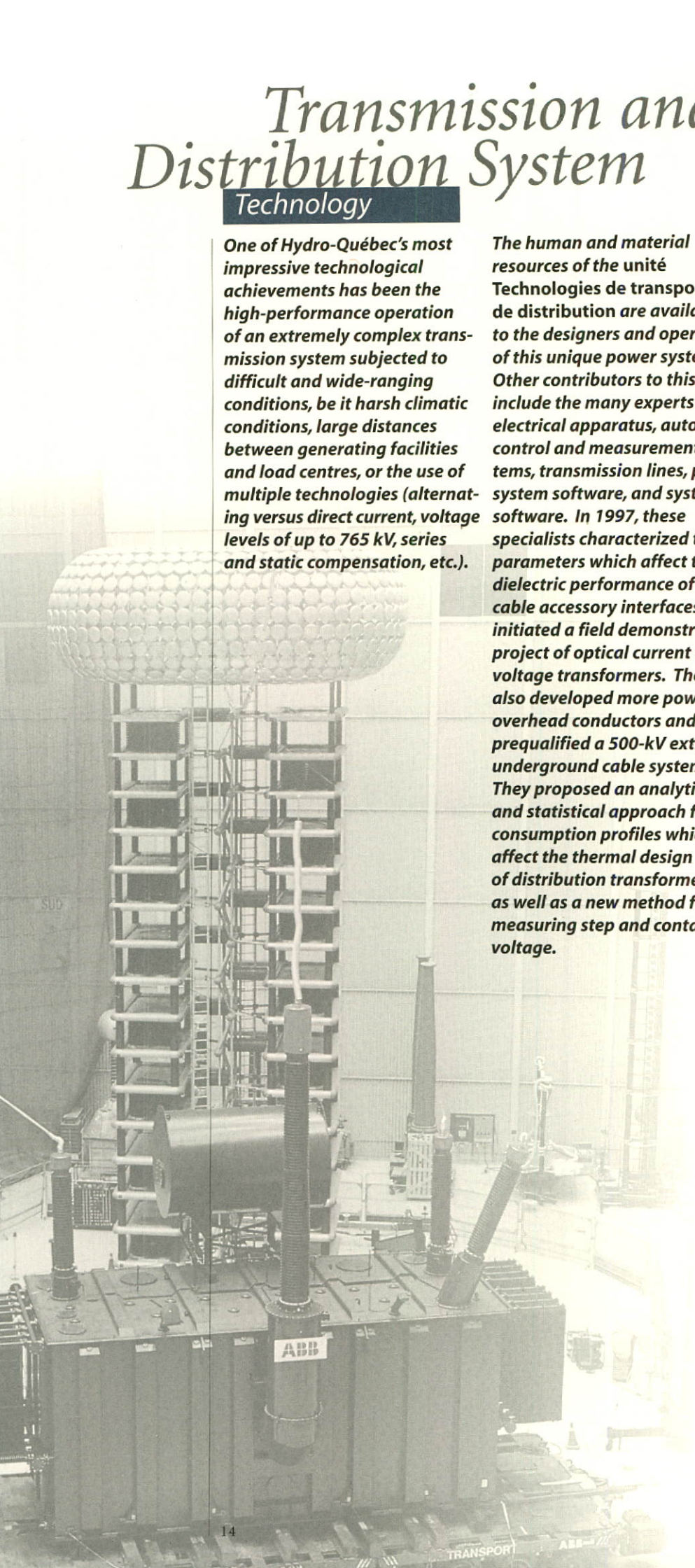
Transmission and Distribution System

Technology

One of Hydro-Québec's most impressive technological achievements has been the high-performance operation of an extremely complex transmission system subjected to difficult and wide-ranging conditions, be it harsh climatic conditions, large distances between generating facilities and load centres, or the use of multiple technologies (alternating versus direct current, voltage levels of up to 765 kV, series and static compensation, etc.).

The human and material resources of the* unité Technologies de transport et de distribution *are available to the designers and operators of this unique power system. Other contributors to this effort include the many experts in electrical apparatus, automatic control and measurement systems, transmission lines, power system software, and systems software. In 1997, these specialists characterized the parameters which affect the dielectric performance of cable accessory interfaces and initiated a field demonstration project of optical current and voltage transformers. They also developed more powerful overhead conductors and prequalified a 500-kV extruded underground cable system. They proposed an analytical and statistical approach for consumption profiles which affect the thermal design of distribution transformers, as well as a new method for measuring step and contact voltage.

These research and development activities also led to the development of remote distribution system fault indicators, as well as rapid measurement of power system variables. A hydroelectric generation planning model was also designed, integrating stochastic natural inflows, as well as a software program for analyzing the integration of wind generation in hydrothermal facilities. Lastly, the past year saw the development of a communications and measurement system for rotary machines, generating station installation models compatible with the ST600 stability software program, and a technology transfer support system which integrates the concept of knowledge management.



Electrical Apparatus

Measurement of step and contact voltages

Grounding systems fulfill several functions in a distribution system. Under normal operating conditions, the voltage on the neutral must be lower than the standardized values. When a fault occurs, the impedance must be low enough to ensure operation of the protective relays and limit overvoltages on the healthy phases. Finally, grounds must ensure the safety of personnel and the general public. Considering the complexity of the grounding system, direct measurement of step and contact voltages is the surest way of checking that the installations are safe.

A newly developed method for measuring step and contact voltages consists in inserting a resistive load on the low-voltage side of a single-phase distribution transformer during a few cycles. This method has numerous advantages compared with the conventional method of causing a phase-to-neutral fault on the medium-voltage network. It benefits customers by preventing fault-related disturbances from occurring, while being ten times more cost-effective for the utility since it eliminates any interventions on the medium-voltage network.

We worked jointly with the *Unité mobile d'essais en réseau* on developing the new method, which will also fill a major gap by providing distribution system line designers with important information on the optimization of the grounding system. Until now, due to the high cost of the measurement process, Hydro-Québec had very little information on the safety of its distribution systems, and this is still the case with other North American electric utilities.

Remote signalling of fault indicators

A system for remote signalling of distribution system faults has been developed on behalf of the *direction Conduite des réseaux de distribution*. The new system, used to improve the service continuity of distribution substations, ensures the remote transmission of values related to the state of indicators and the approximate values of the current flowing in each phase. When a fault occurs, the system detects the defective line and locates the problem, thereby reducing the response time and, by implication, the duration of the power outage. The system is also useful for distribution system load management. In addition to signalling and detecting faults, it provides information on loads and optimizes their operation thanks to centrally available information in the distribution control centres.

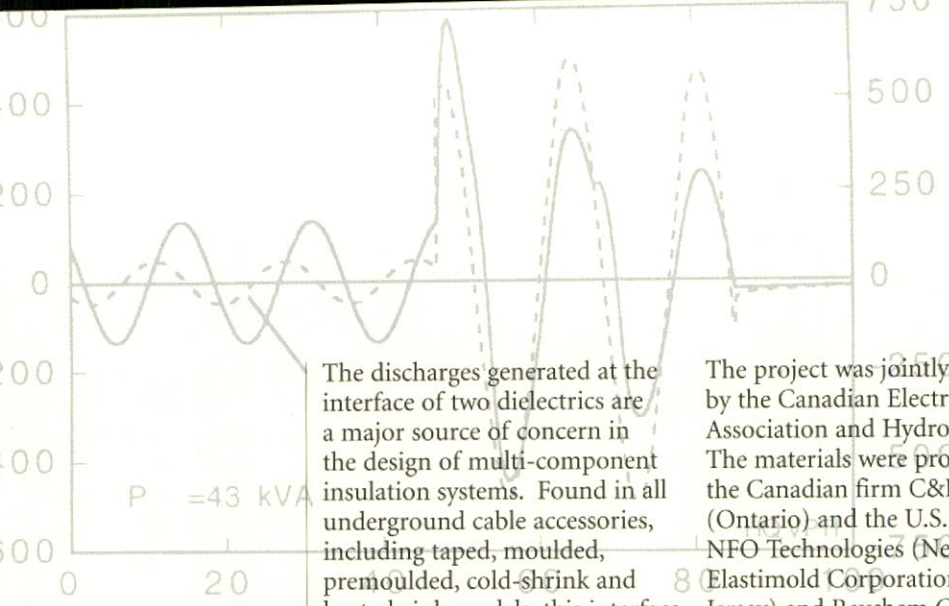
As part of a pilot project, a prototype of the system was installed at Hydro-Québec's Guy substation. It created considerable interest but required the development of a new architecture to solve a problem caused by cables connected to the indicators which had prevented compliance with the clearances. The installations were thus done on de-energized lines, which caused unacceptable delays due to the magnitude of the required switching operations and line contingencies.

Carried out jointly with the *unité Distribution*, the above work involved a first partnership agreement with the French electric utility Soulé-Bardin (see page 37, *Product Development*). Negotiations are under way for the project's second phase.

Transmission Lines

Discharges at the interface of underground cable accessories

We initiated a project aimed at characterizing the parameters which affect the dielectric performance of cable accessory interfaces, then determining the best way of improving their reliability over the long term. The parameters associated with the breakdown voltage of an interface consist of sanding, sliding, greasing, interface pressure, distance between the electrodes, temperature, the waveshape, and ageing.



The discharges generated at the interface of two dielectrics are a major source of concern in the design of multi-component insulation systems. Found in all underground cable accessories, including taped, moulded, premoulded, cold-shrink and heat-shrink models, this interface is the cause of many power system failures.

To better simulate the different interfaces offered on the market and vary the test conditions, we used moulded samples with embedded semi-conducting electrodes. The materials used to manufacture the samples consisted of EPDM (ethylene propylene diene monomer), epoxy and cross-linked polyethylene.

The test and analysis results completed in early 1997 had a direct effect on the composition of greases as well as on the design, test methods and installation of accessories. They also resulted in the following recommendations:

- avoid surface sanding of polyethylene cable insulation when accessories are being installed since there is an insulation screen for distribution cables that is easy to remove and its use reduces installation time and prolongs cable service life;
- revise the duration of the heat time of IEEE-404 upward to allow the pressure of the test joint interfaces to attain mechanical stability.

The project was jointly funded by the Canadian Electricity Association and Hydro-Québec. The materials were provided by the Canadian firm C&P Silicones (Ontario) and the U.S. firms NFO Technologies (New Jersey), Elastimold Corporation (New Jersey) and Raychem Corporation (Delaware).

Field demonstration of optical instrument transformers

We undertook a field demonstration of optical current and voltage transformers. Initiated within a context of technological prospecting, the project consisted in installing several instrument transformer prototypes on a 315-kV busbar at IREQ's high-power laboratory. The current phase, which involves monitoring in-service equipment, is expected to continue for at least another two years, with the project's aim being to evaluate the performance of new technologies over full four-season cycles.

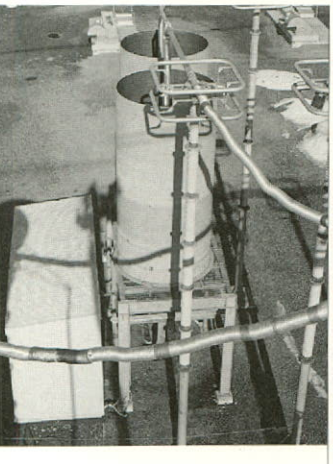
Noteworthy events of 1997 include the computerized gathering of substation data and the installation of a conventional current transformer which will serve as a reference for comparing new devices. It should be noted that the high-power laboratory substation was chosen in order to obtain results more quickly for the evaluation of control and protection devices. This is in fact an ideal demonstration site, since it provides various breaking and reclosing conditions on an active busbar used for the 315-kV test cell. In fact, we believe that a year's worth of monitoring at this substation is equivalent to almost 10 years at a conventional substation where short-circuits and switching operations that are stressful to apparatus occur much less frequently.

This project is the outcome of more than five years of assessing new optical technologies at IREQ, during which time Hydro-Québec always used a two-pronged approach which involved assessing apparatus in the laboratory followed by monitoring in the field. It should be noted that many previous tests had been carried out for the TransÉnergie division in conjunction with or at the request of manufacturers and partners from the electrical industry such as ABB, GEC-Alsthom, Square-D, NGK, NYPA and CITEQ.

High performance of compact homogenous conductors

We successfully completed a project aimed at developing overhead conductors which perform better than the ACSR conductors currently in use at Hydro-Québec, and which can be used as replacements for the latter without jeopardizing transmission line reliability or having to reinforce transmission towers. The focus was on compact homogenous conductors comprised of trapezoidal rather than round strands, manufactured from an aluminum alloy which ensured an equivalent breaking load. Thus, with an equivalent diameter, the transmission capacity of these conductors would increase by over 15% and their joule losses would decrease by at least 25%.

Transmission and



The project consisted in validating these electrothermal properties and demonstrating the general strength of the new conductors. An extensive program was implemented to test the conductors' mechanical strength (stress-strain properties, breaking load, ductility and long-term creep), their tension stringing ability, wind drag, sensitivity to aeolian vibrations, fatigue strength and behaviour under the corona effect, and the effect of high current on the ageing of joint sleeves.

To bring this program to completion, Hydro-Québec joined forces with Électricité de France, which wished to validate its own optimized compact conductors. The drag tests were conducted in a wind tunnel at the National Research Council of Canada's Ottawa facilities, while the fatigue tests were carried out at the mechanical engineering department of Université de Laval, in Québec City.

The overall project was carried out jointly with the *unité Ouvrages civils et Matériaux*, the mechanical and thermomechanical laboratory, and the high-voltage laboratory, and also benefited from the support of the TransÉnergie division. Once the technology transfer is completed in early 1998, the first new conductors will be installed on Hydro-Québec's transmission lines during the year.

Prequalification of a 500-kV extruded underground cable system

In 1995, prequalification tests conducted at IREQ at 345 kV demonstrated the reliability of extruded cables and accessories. This underground cable technology, which uses premoulded or prefabricated joints, has thus proven to be a simple and low-cost alternative compared to cables insulated with paper and oil. Alcatel then conducted prequalification tests at 500 kV on the same cable loop. The 165-m-long loop consisted of a cable with a copper core and a surface area of 1600 mm^2, with an insulation comprised of a 27-mm-thick layer of cross-linked polyethylene (XLPE), a premoulded joint and synthetic rubber stress cones. The outdoor and GIS terminations were filled with SF_6 gas, and the installation in the duct banks and joint manhole was similar to that in use on Hydro-Québec's distribution system.

The tests were carried out following the recommendations of CIGRÉ Working Group 21.03. To simulate the ageing of the cable, a phase-to-ground voltage of 500 kV was applied to the Alcatel cable loop for a period of 365 consecutive days (8,760 hours) following daily thermal cycling (eight hours of heating at a maximum temperature of 95°C followed by 16 hours of cooling). The cable loop and accessories were then subjected to switching surges at 1175 kV and lightning surges at 1550 kV. On October 9, 1997, Alcatel's 500-kV underground cable system successfully completed the prequalification tests at IREQ's high-voltage underground-cable test area. This was a world first for this voltage level for a cross-linked polyethylene cable with a premoulded joint. The project was carried out on behalf of Hydro-Québec's TransÉnergie division.

Power System Software

A hydroelectric generation planning model that integrates stochastic natural inflows and a detailed representation of the generation system

Long-term planning of primarily hydroelectric generation must take into account variations in natural reservoir inflows. However, traditional methods of mathematical optimization cannot be used to directly treat this type of problem, i.e. with stochastic inflow modelling, for a system comprising more than three reservoirs.

As Hydro-Québec owns 24 major reservoirs, the problem is currently being studied using a dynamic stochastic programming approach which first integrates all of the reservoirs into a single energy reservoir and then provides an optimal operating policy for the aggregated reservoir; the next stage involves disaggregation to obtain a detailed operational view. However, a certain amount of information is lost with respect to generating station output and operating constraints in the aggregation process; also, the aggregation procedure is based on heuristic rules which may result in less than optimal operation. This is why the *unité Plan et Stratégies de production* part of the Generation Group was looking for a way to work directly on a detailed representation of the system without having to resort to an aggregation-disaggregation mechanism.

Distribu

In 1996, by combining the concepts of stochastic dynamic programming (DP) and parametric linear programming (PLP) and relying on greater computing power, we formulated a suitable approach, known as "DPPLP," which is relatively simple to implement. In 1997, we submitted it to the *unité Plan et Stratégies de production*, which had mandated us to develop a prototype. The prototype, which was developed in short order, yielded a preliminary experimental validation of the approach in terms of the required computational power and the results obtained. This validation phase should be completed in early 1998 on additional data sets supplied by the client. If it is successful, minor adjustments will be made to the prototype to make it operational during the year. The utility will then have a more powerful tool capable of generating more reliable and precise results, including marginal energy values.

In addition to taking into account the stochastic aspects of inflows, the approach may also be refined to recognize price fluctuations. Also, it may be sold to utilities which are primarily hydro-based.

Éo: Software program for analyzing the integration of wind generation in hydro-thermal facilities

Wind energy is by nature intermittent since it is only available when wind velocities exceed a certain threshold, which varies depending on the type of wind farms involved. Existing data on wind velocities show that the annual generation of wind farms varies more than the runoff for Hydro-Québec's reservoirs. Prior to 1996, however, no software was available that could simulate the integration of wind farms into the utility's power system.

At the request of the *unité Planification des projets de production*, we undertook in late 1995 to develop a prototype for the Éo software program. Using hourly averages for the wind velocity and ambient temperature, the prototype determines the hourly generation of a wind farm with identical turbines and subjected to the same wind and temperature conditions. The calculation was done using the power output curves for the turbine model used based on the weather conditions and the values representing various types of losses.

Transmission

The outcome is taken into account by the Io software program, which evaluates the impact of the wind farm on the requirements with respect to additional means of generation. It should be noted that the Io software program, designed to optimize the generation of hydroelectric and thermal facilities, was especially developed to evaluate the capacity of different generating facilities to meet hourly demand during peak periods.

In 1997, another project led to the creation of a new version of the Éo software program under Windows 95. This considerably upgraded version can now simultaneously process several wind farms using different turbine models and climatic conditions. It also includes a module which validates weather information to be used for calculating wind generation and generates numerous statistical graphs and reports which facilitate the analysis of the results.

ST600 models of Gentilly-2 and Bécancour generating station equipment

At the request of the unité Électricité et Informatique des procédés of Gentilly-2 generating station, we successfully completed a research and documentation project on Gentilly-2 and Bécancour generating station equipment models in order to make them compatible with the current versions of the ST600 stability analysis software. The models, which have been documented and are operational, are available to Gentilly-2 users as well as the direction Exploitation, which also collaborated on the project.

The modelled equipment consists of the Gentilly-2 steam turbine, its control and speed-setting device, generator, excitation circuit and voltage regulator, the 6.7-MW asynchronous cooling-system motors, the backup diesel units and the Bécancour generating station gas turbines.

In 1983, IREQ and various consulting firms started conducting numerous modelling and simulation studies on the above equipment. However, the models, along with the power system and machine data required for their simulation, were spread out among several workstations and different versions of the RP600 and ST600 software programs were being used for the simulations. In addition, documentation on the models and simulations was often inadequate or nonexistent.

The project consisted in first extracting from available reports the information required to compile better documentation on the models and then finalize it, and to check the parameters used for the simulations. We thus managed to integrate all of the modelling work done since 1983, as well as determine model upgrading or development requirements in order to obtain a better representation of the behaviour of Gentilly-2 and Bécancour generating stations in transient stability studies.

and Distribution

The project will also facilitate technical follow-up of the automatic controls and settings based on changes made to the generating stations and the overall power system. This is of primary importance for Gentilly-2 generating station, which, because of its special nature, must comply with the most stringent operational standards.

Development of a MATLAB-EMTP interface

We have completed a project aimed at integrating the MATLAB simulation and programming environment with the Electromagnetic Transients Program (EMTP). The highly sophisticated MATLAB software program is currently very popular in the scientific community, especially among engineers. Because of its high-level analysis, simulation and display environment, a varied range of concepts and tools can be easily applied to complex problem solving.

For its part, the EMTP software program has been used on an international scale for in-depth simulation of transient phenomena in power systems. Its main advantages are its computing power, which is especially suited to large-scale power systems, and its many models, which have been adequately validated on operational networks and laboratory models. However, the system's lack of user-friendliness slows down the model-building process and reduces the interaction required for simulation processes.

The MATLAB-EMTP interface, on the other hand, substantially improves the user-friendliness of the EMTP software program. It thus allows the models and systems created or simulated in MATLAB to be connected to networks assembled in EMTP using two interconnection options. The first, "direct interconnection," allows for simultaneous startup of two software programs and exchange of simulation results using a configuration that can be modified by the user. "Indirect interconnection," the other option, is based on the possibility of generating the C code of a system assembled in MATLAB and then transparently incorporating it into EMTP's main code.

The new interface presents numerous advantages with respect to the design and analysis of electrical networks. For instance, it allows direct application of protection algorithms programmed in MATLAB in order to simulate the behaviour of an overall protection system, which has been simultaneously incorporated into the EMTP-simulated network. In addition, the complex control systems represented through SIMULINK (a MATLAB tool) can now be directly connected to the EMTP-simulated networks.

Made possible through a partnership agreement between Hydro-Québec and Électricité de France, the project was carried out by the *unité Logiciels de réseau.* The Hydro-Québec client was the *service Études de réseau et Critères de performance* part of Hydro-Québec's TransÉnergie division, and the EDF client was the *direction Études et Recherches* part of the *service Matériel Électrique.* The next step will be to market the new interface.

Analysis and synthesis of load profiles

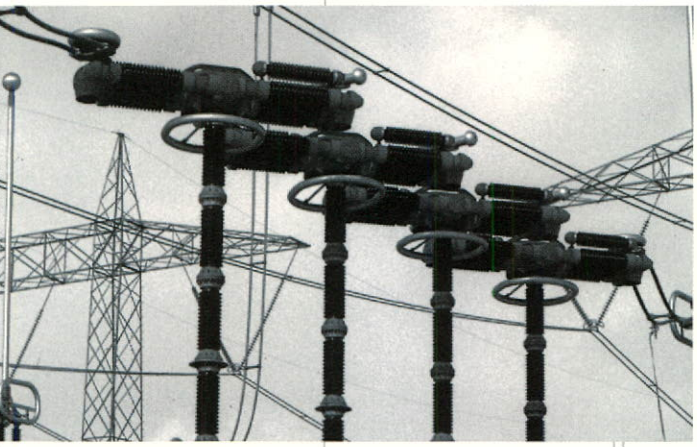
In conjunction with the *unité Orientations* part of Hydro-Québec's *direction Orientations et Plans du réseau de distribution,* we undertook a project which involved developing an analytical and statistical approach for determining the parameters used in obtaining a synthesis of load profiles (used in the thermal design of distribution transformers), as well as verifying the calculation of these profiles at different points of the network, including during cold load pickup.

Given the lack of sufficiently detailed load data, distribution transformers are usually designed based on the estimated winter and summer peak load in kilowatts, as well as various safety factors. However, this approach has the following disadvantages:

- at equivalent peak power and compared to a load with a considerable utilization factor, a small transformer may be sufficient for a load with a lower utilization factor;
- thermal ageing is a cumulative process, so the annual utilization factor has an effect on transformer design;
- the diversity of the load, a function of the number of customers connected to the transformer, is not taken into account;
- variations in climatic conditions are not known.

The aim of the project is to develop a modelling tool that will help power system planning engineers select the most efficient and cost-effective equipment.

Transmission and



Systems Software

Automatic generation of single-line diagrams using the HYPERSIM digital simulator

We added a module capable of automatically generating single-line diagrams to the HYPERSIM all-digital power system simulator, designed by the *unité Simulation de réseaux* and marketed by Hydro-Québec's Teqsim division. As the interface with the simulator is produced using a diagram editor developed by our team, we thought it would be useful to generate the related specifications automatically in the form of diagrams using EMTP files.

The interface already included a sophisticated automatic positioning algorithm for creating diagrams, so all that remained was to develop a filter program for converting EMTP files into a language which the algorithm could recognize. However, a few problems first had to be resolved, such as the generation of single-line diagrams using a general representation (not three-phase) and the simplification of these diagrams by replacing several graphic elements with numerical values corresponding to the HYPERSIM elements. In fact, each diagram symbol would include data entry parameters for electrical specifications, and the symbol could contain several elements from the EMTP file.

The new conversion program has already proven to be very useful in designing a Hitachi network, as simulation specifications could be drawn up more quickly using a sophisticated EMTP file.

It should also be noted that the automatic positioning algorithm is now capable of generating bidirectional diagrams which are more precise than those obtained manually with the editor. However, to automatically create adequate diagrams which meet users' requirements without additional editing, major heuristic studies will have to be conducted regarding a series of related and allegedly unsolvable problems.

Regional Control Centres in the year 2002

Regional control centres (RCCs) are the main suppliers of data acquisition and control systems for the utility's substations and generating stations. An integral part of Hydro-Québec's power system, RCCs are responsible for ensuring the reliability and continuity of the electrical supply, as well as power quality. Faced with a new industry context and output requirements for electric utilities, RCCs must adapt their major power system management systems in order to meet optimal demand, manage generating and transmission facilities more efficiently, and integrate control and operational tools.

Accordingly, a task force was set up to determine the R&D needs of the regional control centres from 1998 to 2002, and to suggest how they could meet the challenges created by the new power system management framework. The project was carried out jointly by the *direction Téléconduite* (TransÉnergie), the *unité Informatique de transport* (TransÉnergie's *direction Plans et Programmes*) and the *unité Logiciels de systèmes* (IREQ's *unité TTD*).

The report produced by the task force first reviews the situation with respect to the new power system management context, infrastructures, the utility's corporate vision, new and emerging technologies, and R&D's role in anticipating future changes. It then assesses the means to be implemented in order to meet our shareholder's commercial requirements and handle these changes. The report also discusses how CCRs have evolved in relation to trends among North American utilities and defines their position vis-à-vis the utility's other areas of interest according to a structure which will eventually be in line with a future intelligent power system.

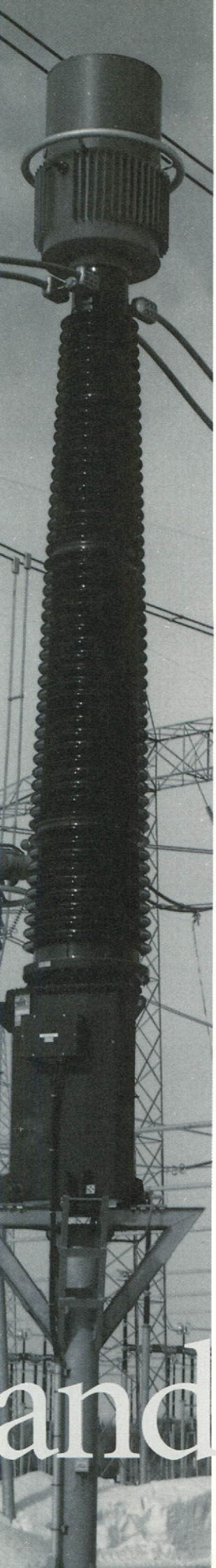
Finally, the report proposes a framework for meeting new needs as well as a series of technical and administrative measures to be implemented so that the CCRs can continue to fulfill their mandate.

The SATT knowledge management project

The concept of knowledge management encompasses all of the measures implemented by a company to transform its knowledge into assets by allowing access to its current know-how, speeding up its transfer, and ensuring that it is up-to-date. We used this concept as a basis for the SATT project (*système d'aide au transfert technologique* – technology transfer support system), whose applications may be used to transmit an employee's expertise, standardize instructions for personnel, and improve professional development.

To successfully carry out this project, we also studied the relevance of the task support concept in meeting our business needs. The concept is designed to support employees in their actions and thought processes with the assistance of four virtual players: the consultant, the trainer, the librarian and the technical assistant.

With respect to the actual technology transfer, we created two tools. The first, known as "Gabriel," consists of an inference engine used to manipulate knowledge in a given field. Its uniqueness lies in its synthetic programming language which is similar to human language (French), as well as its interactive mechanism which allows users to obtain explanations based on their intentions. The second tool, known as "ASC" (*aide à la structuration des connaissances* – knowledge-structuring support system), is more basic and only allows users to structure static knowledge. Non-computer experts are thus able to organize knowledge in their field of expertise.



The next step will be to perfect ASC so that it can capture and organize active knowledge used to develop task support system functions. "Assistants" will also be incorporated into ASC in order to help designers create the databases needed to activate the virtual players described above. Over time, the SATT project should promote the transfer and commercialization of the utility's know-how.

Automatic Control and Measurement Systems

Field demonstration of efficient algorithms for measuring power system variables

As a result of new computer technology and global positioning systems (GPS) with a higher degree of precision and reliability, new variables can now be used in power system automatic controls and the control loops which act on power system stabilizers, static or synchronous capacitors and HVDC converter regulators. However, Hydro-Québec's series-compensated transmission system has natural oscillation modes which introduce measurement errors likely to have an adverse effect on the operation of automatic controls and control systems.

At the request of the *unité Études de réseau et Critères de performance*, we had initiated an R&D project in 1993 aimed at obtaining fast measurement of power system variables. The project led to measurement and filtering techniques which were then validated using EMTP parametric and simulation data. As the validation proved to be conclusive, a field demonstration phase was initiated in August 1995. The algorithms were implemented on two synchronized phasor measuring units scheduled to be installed at Boucherville and Némiscau substations. During the same development phase, the SCADA unit, located in IREQ, was set up to receive the local values of the measuring units by modem and compare them in order to obtain the general variables used in the automatic controls and control loops. Network testing for the two substations is scheduled to begin in early 1998.

Concurrently, a third phasor measuring unit will be designed and installed at Arnaud substation to facilitate monitoring of the transmission system's entire eastern sector. The evaluation of the performance of this measuring system, which is expected to continue until the end of 1999, will serve to validate and fine-tune the algorithms while providing a follow-up of the series-compensated network.

Modal analysis: design validation and application on control systems

As the number of interconnections rises, networks are increasingly exposed to low-frequency inter-area oscillations. Analytical tools have therefore been developed to quantify the natural modes which characterize small-signal stability and to design preventive measures using improved control systems. However, there was a major dimensioning problem inherent in the approach used, i.e. direct linearization of dynamical equations, the most intuitive approach for obtaining a linear model of the power system. A network of 2,000 dynamic components can in fact have up to 3,000 state variables, which makes this approach unfeasible unless the power system is first reduced.

Starting in 1991, IREQ began using time-domain simulation software to determine, by means of numerical state-space identification, the "black box" models which accurately depict the behaviour of the overall power system. In addition to producing reduced models tailored to the modern control system design tools, this approach made full use of dynamic stability software models. This effort initially led to the implementation in 1993 of a course in modal analysis which was appreciated by Hydro-Québec's planning and operational engineers.

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Two years later, the *unité Programmes et Stratégies du réseau principal* commissioned us to carry out a more in-depth research project with a view to meeting the following three objectives:

- improve and validate modal analysis by integrating it in the ST600 (Hydro-Québec) and PSS/E (PTI) software programs, followed by a comparative study with a recognized software program;
- develop tools for analyzing the performance and optimal siting of controllers in a large network;
- apply sturdy new control systems based on multi-band and multi-loop stabilizers to the optimization process.

In the meantime, the *unité Études de réseau et Critères de performance* proceeded to computerize modal analysis on a large scale so that it is now capable of producing models (A, B, C, D) at 26 inputs and 26 outputs using pulse responses. These models allowed the task force responsible for revising the voltage regulator parameters to upgrade current stabilizers and propose an optimized multi-band stabilizer for Sainte-Marguerite generating station.

New communication and measurement system for rotary machines

An in situ test program was used to validate an all-new wireless measurement and communication system for rotary machines, which will allow continuous measurements to be made directly on the rotor while generators are in operation. It is difficult to obtain truly accurate measurements on the generator's rotating parts (rotor, shaft and turbine) using currently available methods. For instance, wear in collector rings causes stray noise, while the disadvantage with traditional wireless solutions is that the rotation causes interference or total loss of the signal.

We therefore installed a wireless Ethernet bridge on the rotating part of the generator as well as an all-new antenna which allowed us to establish a reliable and flexible bidirectional communication link. The measurements are transmitted to the computer, which is used for data storage and processing rather than the measurements themselves. For demonstration purposes, only a few reference parameters were measured, such as temperature, voltage, acceleration and the air gap. The power supply was provided through rotor excitation, while an integrated battery allowed measurements to be taken during startup and shutdown sequences.

While this assembly was in operation for several days on generator 13 at Carillon generating station, the client noted that remote data acquisition and transmission could be carried out reliably and continuously on the rotating parts. Preliminary analysis of the measurements confirmed that key parameters for generating-unit monitoring may now be measured directly and with great accuracy.

Integration of the latest electronic, communication and computer system technologies will yield production prototypes capable of being installed on most types of rotors. It will then be possible to access generator rotors directly from a workstation by intranet.

Application Technology and LTEE

About ten years ago, in order to integrate its R&D efforts with industrial applications of electricity, Hydro-Québec combined its resources in this area to create LTEE, Hydro-Québec's electrochemistry and electrotechnologies laboratory (Laboratoire des technologies électrochimiques et des électrotechnologies). *The utility had mandated its new laboratory to support the commercialization of electricity, a mission which included electrochemical and metallurgical processes as well as industrial applications, and which now comprises residential, commercial and institutional applications of electricity.*

The past year, which marked the end of the first decade of research and development in the utilization of energy, proved to be especially successful. First, the scope of the laboratory's ISO-Guide 25 accreditation was extended to cover the electromagnetic compatibility of variable speed drives (VSDs). As part of a power-quality program, the related test bench was used to characterize the electrical susceptibility and performance of four types of 115-kW VSDs.

Other LTEE projects included an in situ measurement method developed to assess the performance of electrical motors and a project designed to set up a series of membrane filtration units for treating meat industry waste. Moreover, the PAQET project, aimed at evaluating the impact of work designed to improve the quality of thermal envelopes on multi-unit buildings, led to the implementation of a methodology and remote-measuring infrastructure as well as the analysis of data.

LTEE continued its work with the PAIE program by providing technical support to Hydro-Québec personnel in regional sectors. Laboratory researchers also conducted tests with a view to recommending electrotechnologies which best meet client needs. The development of ultrathin film processes for lithium-polymer batteries continued and an agreement was signed regarding the Droscar process. Finally, work was done with a view to developing an original process for synthesizing azelaic acid.

Residential, commercial and institutional applications

PAQET project

The objective of the PAQET project is to evaluate the impact of work designed to improve the quality of thermal envelopes on multi-unit buildings. In the fall of 1995, devices were set up to obtain detailed measurements of the electricity consumption of 51 buildings containing 2 and 3 apartments each (PAQET I) and 43 buildings with 4 to 8 apartments (PAQET II). In the summer of 1996, insulation and sealing work was done in 62 of these buildings in an effort to reduce the customers' heating bill. In addition to setting up the methodology and the remote-measurement infrastructure, LTEE analyzed the data gathered during the first two winters for purposes of comparing consumption before and after the work, using different methods of analysis. The measuring devices were removed from 44 buildings in the spring of 1997.

Data gathering will continue in the 50 remaining buildings until the spring of 1998. Data for the third winter will then be analyzed in order to produce a final report for the *unité Utilisation de l'énergie*, which had asked LTEE to carry out the study as part of its "Isolaction" commercial program.

The Centre québécois de l'électricité (CQE)

The aim of Hydro-Québec's commercial orientation is to step up the utility's presence among commercial customers to increase its electricity sales, as well as provide key information on electrical technologies. A new centre was set up to support this approach, the *Centre québécois de l'électricité* (CQE), whose mandate is to transmit the know-how developed under the utility's technology plan to Hydro-Québec sales personnel and customers.

As a first step, the CQE asked LTEE to gather technical documentation on lighting and electrical curing. The first area accounts for 30% of the revenues brought in by the commercial and institutional sectors, while the second presents several little-known benefits in terms of energy output and decreased ventilation, which explains certain choices based on overestimated consumption.

The documentation gathered by LTEE was distributed to commercial representatives to help them prepare for meetings with customers. LTEE also set up a toll-free phone number for major customers and regional representatives requiring additional information on the above-mentioned areas. In 1997, customers were also given technical data and the proceedings of conferences to which they had been invited. The CQE expects to launch similar initiatives in fields such as infrared heating and geothermal energy.

Energy management and time-of-use rates (rate DH)

Rate DH, a time-of-use rate intended for residential customers, was added to Hydro-Québec's 1997 rate policy. Implemented on a trial basis, the new rate consists in a peak/off-peak rate which encourages customers to reduce their electricity consumption during peak periods. Concurrently, LTEE also completed a huge project with a twofold objective: develop a mechanism to promote the commercialization of rate DH by identifying target customers, and evaluate and recommend energy management devices which will ensure that residential customers fully benefit from the new rate.

Local and central thermal storage devices used to manage the heating of dwellings were thus evaluated, as were storage water heaters used to manage hot-water consumption. These two devices allow customers to store, during off-peak periods, the energy needed for their peak-period requirements. Laboratory and in situ tests confirmed that they take the strain off residential heating systems and water heaters for 16 consecutive hours. Other research focused on ways of controlling the devices to attenuate the effect of simultaneous startup at the beginning of off-peak periods. This work led to the development of controllers for thermal storage devices and water heaters. Testing of the controllers at customers' premises revealed that use of the devices during equipment startup led to a substantial decrease in power demand compared with the conventional timer-based device.

Rate DH will most likely only see limited use due to economic conditions, deregulation, and the potential development of a multifunctional meter which will ensure an even more flexible time-of-use rate. The project, however, did provide LTEE with expertise which, starting in 1998, will be used to develop an integrated management design combining management devices with home automation.

Industrial Applications

Electromagnetic compatibility

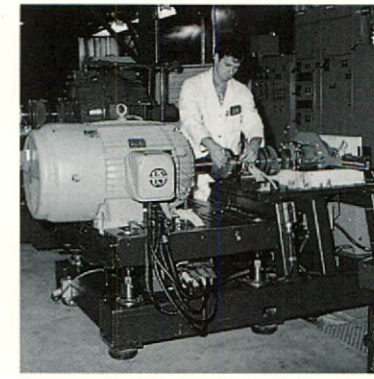
After an audit was conducted in July 1997 by the Standards Council of Canada, the scope of the ISO-Guide 25 accreditation obtained by LTEE in 1993 was extended, subject to the implementation of a few corrective measures, to cover the electromagnetic compatibility (EMC) of variable speed drives (VSDs). The test bench used for this purpose is comprised of unique equipment, including a 432-kW three-phase amplifier, the main cog in the study of the susceptibility of electronic apparatus sensitive to power system disturbances. Two projects on power quality were thus carried out as part of a power-quality program.

The first project consisted in characterizing the susceptibility and performance of four types of 115-kW variable speed drives. Carried out jointly with EPRI's Power Electronics Center, the work led to the development of test protocols that can be applied to industrial-power VSDs (> 40 kW). As part of another project, we were asked by an external client to improve the performance of VSDs when exposed to voltage dips. In addition, we contacted specialists from France (EDF), the United States (EPRI) and South Africa (ESKOM) with a view to setting up a committee charged with drawing up an international characterization standard for VSD susceptibility to voltage dips.

The second project, which involved the susceptibility of electrical and electronic equipment to voltage variations, allowed us to establish voltage dips that are potentially harmful for residential customers; this information will be of use to the *unité Plaintes et Réclamations* (complaints and claims department) in handling such queries from customers. Since the project was initiated, 125 devices considered to be sensitive were subjected to voltage variations, which allowed a realistic curve to be established for the susceptibility of residential equipment. We were also able to determine that the supply voltage had not caused the failure of certain equipment for which our customers had been compensated. The study's objectives for 1998 will involve sensitive equipment used by commercial, institutional and industrial customers.

In situ measurement of electric motor performance

We are working on developing an in situ method for assessing the performance of electric motors, which will allow us to measure speed and electric variables without having to stop the motors, thus keeping the costs and inconveniences of the operation at a minimum.



LTEE

The industrial sector relies heavily on electric motors, whose excellent performance, however, is regularly criticized due to the energy they use and the resulting impact on the environment. Still, not much is known about the performance of motors that have been in service for several years or which have been repaired or rewound. Meanwhile, motors with an energy efficiency rating which no longer meets current standards could potentially be replaced with new high-performance motors. But in order to evaluate the cost and return on investment of such an operation, the performance of in-service motors must first be determined as well as the function of the load and utilization factors.

However, current in situ measurement techniques involve certain limitations which not all operators are willing to accept. They also require human resources, which increases the cost of the operation, and test devices which take up as little room as possible. To step up the adoption of high-performance motors by the industry, we had to develop a method which minimizes these disadvantages.

We thus decided to model an induction motor operated under both ideal and non-ideal conditions, in steady state and energized conditions, in unbalance, deformed by harmonics, and with an amplitude lower or higher than the nominal voltage. We used simulation to validate certain elements of the model and studied its operation using different load points. A test area was also installed to assess the methods used to identify the motor's parameters. For instance, we incorporated the libraries required to operate the identification algorithm, which will continue to be operated in 1998.

Future studies will deal with motors operated in dynamic state, according to changes in the power setting induced by the load or power supply as well as fast and slow cycles. The work first took place in the laboratory, where we obtained the data used to develop the model and the parameter-identification algorithm. We then studied the efficiency of the measurement method on different makes of motors.

Electrotechnology Implementation Assistance Program

LTEE is taking part in Hydro-Québec's Electrotechnology Implementation Assistance Program by providing technical support to Hydro-Québec personnel in regional areas. The laboratory is also carrying out feasibility and performance demonstration tests for various industrial applications in order to recommend electrotechnologies which best meet customer needs. The studies are also used to determine the preliminary equipment design parameters manufacturers need to obtain bids. LTEE also conducts studies, literature reviews, preliminary calculations and factory measurements on electrotechnologies to support new installations or reinforce existing ones.

In 1997, some 90 industrial projects were handled at the request of Hydro-Québec's Montmorency, Richelieu, Saint-Laurent, Saguenay and Laurentides regions, and four studies were carried out as part of joint agreements with industry.

Electrochemical and Metallurgical Processes

Droscar-Resimix process

Droscar is a process used to recover non-ferrous metals, in particular aluminum, whereby an electric arc is generated in a furnace revolving around two carbon electrodes. The Droscar process will soon be combined with a related technology, known as "Resimix," which extinguishes the molten metal and ensures more efficient recovery of the dross.

Initiated about a decade ago, the Droscar project systematically passed all of the technical development milestones, including large-scale demonstration, with over 700 tonnes of dross having been processed to date for industrial customers. However, until now a patenting problem had prevented it from being put on the market. The problem was solved this past year and Hydro-Québec can now market the Droscar-Remix process outside of North America.

A licensing agreement has now been signed with the French firm Soyer S.A. to set up an industrial unit in France. Another licensing agreement is currently being negotiated with Goswell Development to implement a second unit in South Africa.

The project, carried out for the *direction Commercialisation de la technologie et Participations*, benefitted from the collaboration of Électricité de France, the French firms Exhor and Thermco, and the Chicoutimi-based Québec consulting firm STAS. The first two Droscar-Resimix plants should be commissioned in 1998.

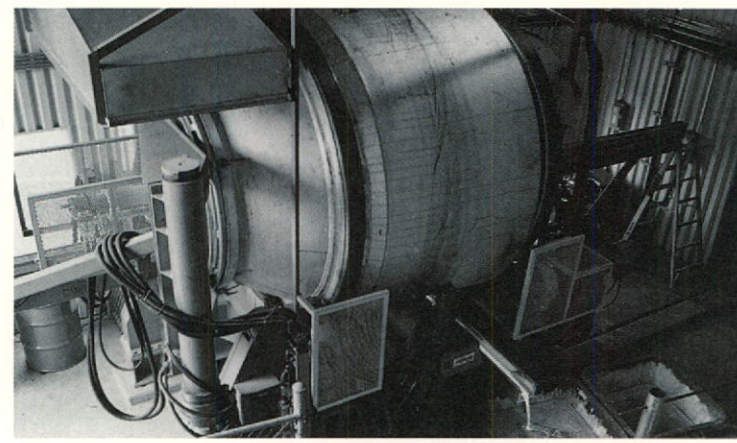
Treatment of meat industry waste

We have successfully completed a project aimed at developing a series of membrane filtration units (ultrafiltration followed by reverse osmosis) for treating waste from the meat industry, one of worst industrial polluters in Québec. A major consumer of drinking water, the slaughterhouse industry is also responsible for discharging a heavy organic pollution load. Current treatment systems are comprised of air flotation units which only partially eliminate this organic load. In fact, the municipalities involved are the ones who complete the treatment process, as most slaughterhouses have signed an agreement with them for this purpose.

However, considering the budget cuts made by these municipalities, the cost of drinking water, and increasingly stringent environmental regulations, more and more meat processing plants are looking into reducing pollution at the source and closing water supply systems. To apply these measures, which lean toward the concept of "zero effluent," membrane separation techniques are of considerable interest. They ensure the production of effluents of consistent and adequate quality for total or partial recycling of the water used in industrial processes.

For the time being, these techniques mainly reduce the environmental impact of industrial activities. But as environmental protection has become for many industries a key competitive factor, Hydro-Québec's customers are increasingly conscious of the usefulness of these high-tech filters. Work carried out in this sector also involves recycling of waste acid in the metallurgical industry, development of a technological sequence for the closing of water supply systems in the de-inking industry, and production of drinking water for small municipalities.

In 1994, we undertook a series of initiatives aimed at determining industry needs, identifying business opportunities, and demonstrating the technical feasibility of membrane separation under laboratory conditions. Last year, in light of these results, we were able to conduct factory demonstration tests in collaboration with a major Québec manufacturer. Lasting 200 hours, the tests allowed us to validate the technology and integrate it into the client's processes.



The project, which was previously part of the mandate of the *unité Stratégies et Développement, Ventes – Grandes entreprises*, has been headed by the *unité Clientèle d'affaires* since the restructuring at Hydro-Québec. It was carried out jointly with the *Centre de transfert de la technologie* part of the Cégep de Shawinigan, through the institution's *Centre national en électrochimie et technologie environnementale* (CNETE). Following analysis of the tests conducted in the plant by the industrial client, the project may lead to the commissioning of 100/200-kW units.

Production of azelaic acid using electrochemical synthesis

A project aimed at developing an original synthesis process for azelaic acid, a chemical found in many plastics, was undertaken at the request of the *direction Développement de produits part of the direction principale Recherche et Développement*, jointly with Prolab, a company based in Black Lake, Québec.

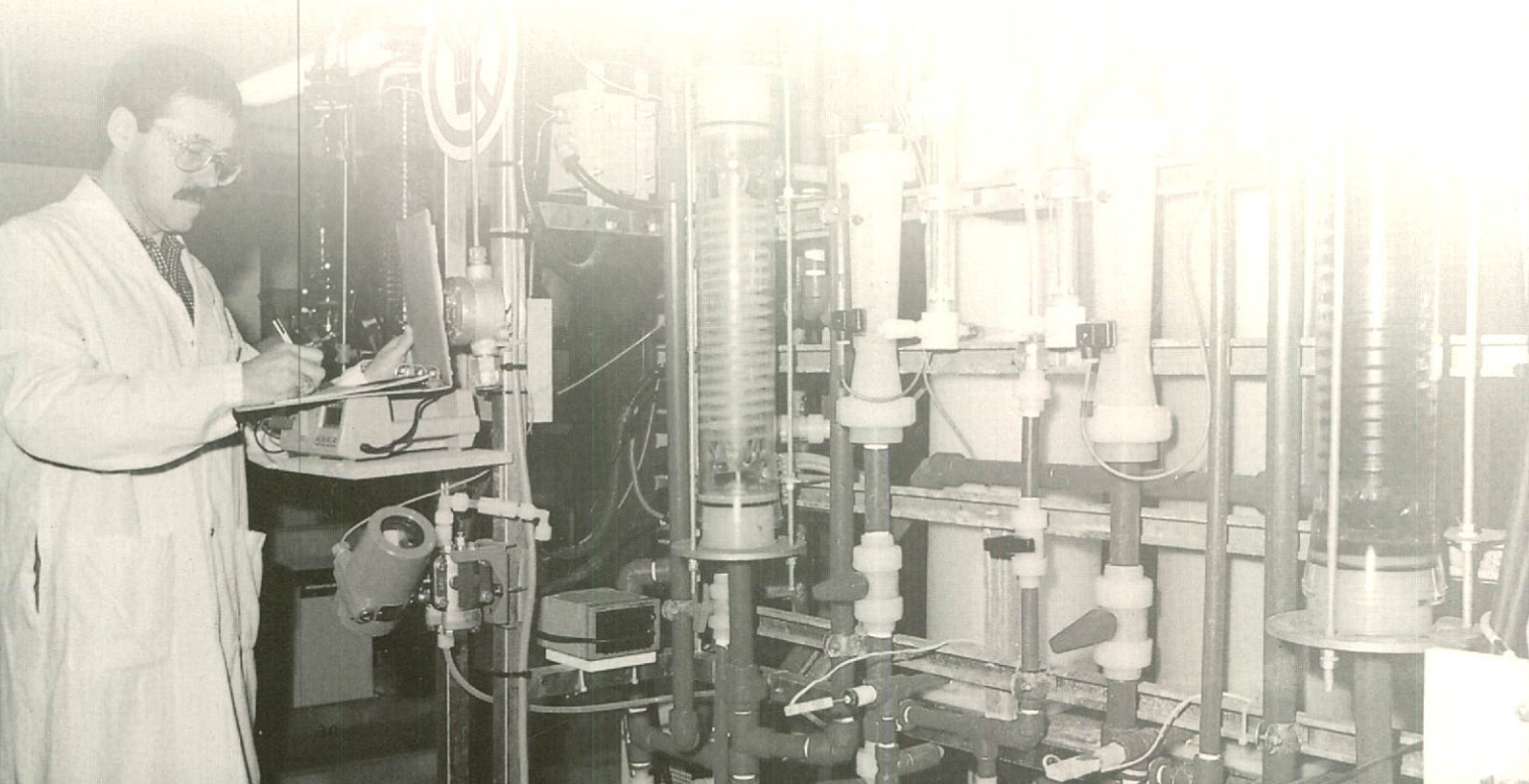
For the past three years, Hydro-Québec and Prolab have been working on developing an electrochemical synthesis process for azelaic acid, a market for which there is only one producer in the world. As a result, there is heavy demand for diversified production and a better quality product at a lower cost. After conducting several market and feasibility studies, the partners agreed that it would be useful to carry out a large-scale demonstration in a pilot plant which would allow them to develop the new synthesis process until the pre-marketing stage.

This year's work has allowed us to complete the technical feasibility studies as well as the technical and economic studies and market studies commissioned by the Hydro-Québec directorate in charge of the project. For 1998, we plan to conduct an industrial demonstration of the process at LTEE's electrosynthesis pilot plant, which will require an investment of $650,000.

Ultrathin-film processes

LTEE continued to work on developing the most efficient and least costly ultrathin-film processes, as provided for in several development programs for the lithium-polymer battery technology. These programs include the agreement signed by Hydro-Québec and its partners with the United Advanced Battery Consortium (USABC), whose aim is to develop all-solid lithium-polymer batteries (see page 38 in the section on Product Development).

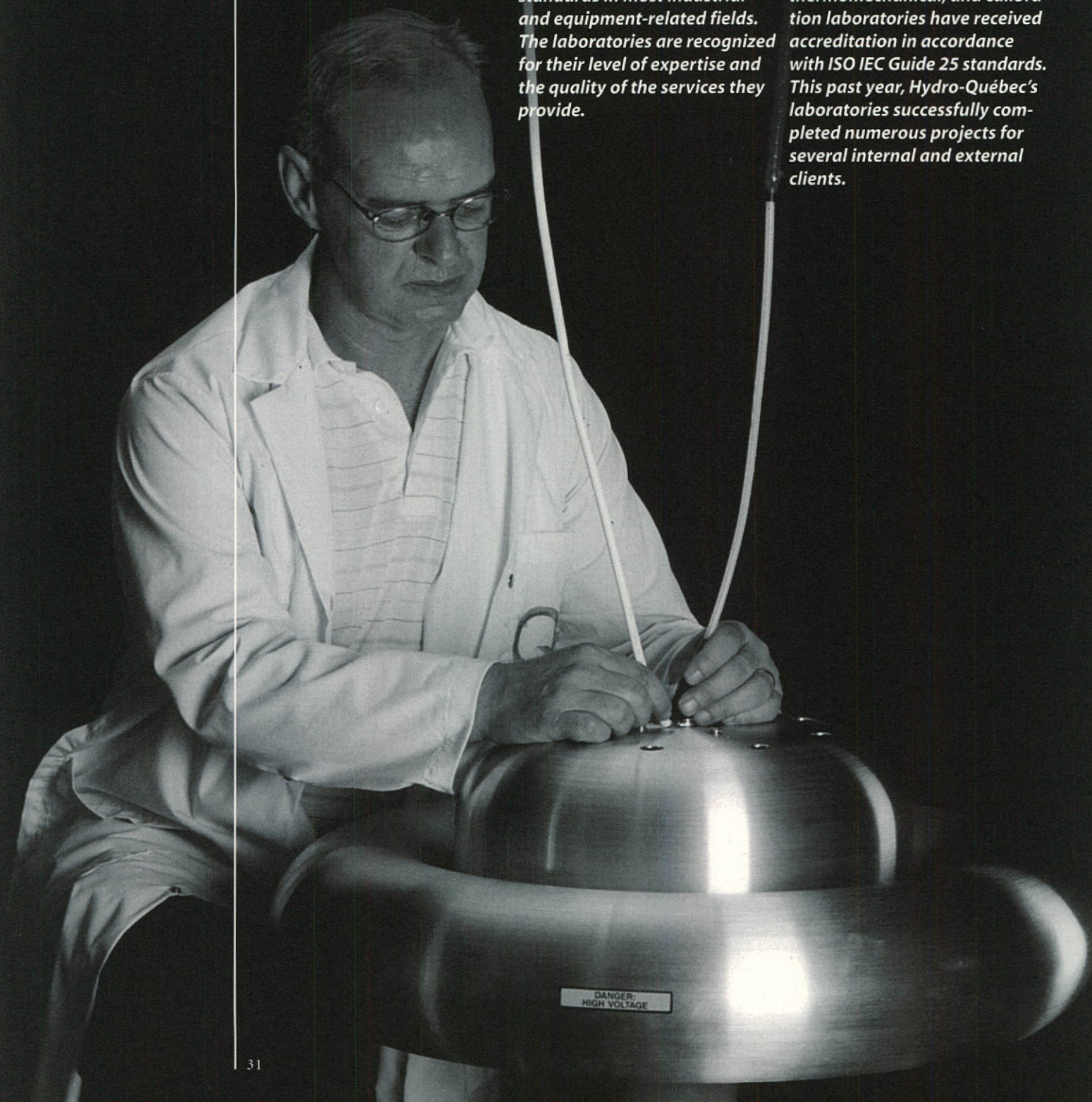
LTEE's work, which is also geared toward developing batteries which run at ambient temperature, as well as primary batteries and varied related prospects, focused in 1997 on starting up projects related to spread coating processes.



Laboratories

Hydro-Québec owns impressive testing installations, both in terms of their size and facilities as in the scope of the work being carried out. Grouped in 1997 under the unité Laboratoires *part of the* direction principale Recherche et Développement et IREQ, *the utility's six laboratories – high-power, high-voltage, mechanical and thermomechanical, power system simulation, field-testing unit, and calibration and repair – offer a vast range of integrated analysis, diagnosis, testing and measurement services carried out according to international standards in most industrial and equipment-related fields. The laboratories are recognized for their level of expertise and the quality of the services they provide.*

In keeping with changing needs and technologies, new high-tech equipment is constantly being added to the test facilities, as well as test benches and testing areas capable of meeting the requirements of an increasingly diversified clientele. The high-power, high-voltage, mechanical and thermomechanical, and calibration laboratories have received accreditation in accordance with ISO IEC Guide 25 standards. This past year, Hydro-Québec's laboratories successfully completed numerous projects for several internal and external clients.



High-Power Laboratory

As its name implies, the high-power laboratory is used to study phenomena in which electrical power plays a key role, such as arcs and short-circuits, in order to determine their effect on different apparatus. During the past year, efforts were geared toward improving methods and installations, and major test programs were carried out. The following is a summary of the laboratory's activities.

Synthetic test station

Initiated in 1994, the project aimed at improving the operation of synthetic tests on high-voltage circuit breakers ended with the replacement of laser-triggered systems with spark-plug-triggered systems. The new devices allow circuit triggering to be synchronized to the nearest microsecond, a factor which is critical to the success of the tests. The devices also improve the reliability of the test installation, as confirmed by a large number of triggering tests, all of which were successful.

Three new reignition circuits developed by the laboratory were also validated; they prolong the duration of the arc of the test circuit breaker by producing a steep current pulse at zero crossing. Lastly, tests will be carried out early in 1998 on a new controlled spark gap for synthetic fault closing tests, equipped with new components used to produce transient voltages which comply with international standards.

Sequencer programmers

The laboratory acquired three new sequencer programmers for editing, configuring, validating and displaying test sequences. Testing efficiency and reliability is thereby improved through increased synchronicity and control of test equipment. IREQ's *unité Systèmes d'automatismes et de mesure* collaborated on this project.

Main tests

- Tests on 38-kV circuit breakers with very rapid transient recovery voltages conducted for large manufacturers.

- Tests to determine the resistance to internal fault arcs of metal-enclosed apparatus at currents of up to 63 kA.

- Short-circuit current withstand tests on Canadian and U.S.-manufactured transformers.

- International standard certification testing of dead-tank circuit breakers and metal-enclosed bus circuit breakers rated up to 145 kV.

High-Voltage Laboratory

IREQ's high-voltage laboratory is one of North America's largest research and testing centres for high-voltage power lines and apparatus. Below is a list of the major tests carried out in 1997 for both internal and external clients. Most of these tests will continue in 1998.

Accelerated ageing tests for HVAC cables

Initiated in 1995, this test program led to the qualification of an XLPE cable rated over 345 kV.

Tests on 765-kV compressed-air PKV8A circuit breakers

Modifications were made to these circuit breakers, installed on Hydro-Québec's series-compensated network, in order to solve a dielectric withstand problem. At the request of the TransÉnergie division, type tests conducted on a modified circuit breaker confirmed that it fully met the utility's standards and requirements.

Tests on a 775-MVA transformer

A major type test program, including short-circuit tests, was carried out on a new 775-MVA transformer manufactured for Hydro-Québec at ABB's Varennes plant.

Laboratories

Laser-triggered lightning tests

The laboratory set up the test assembly and began preliminary testing as part of a major test program on laser-triggered lightning, itself part of a larger two-year R&D project.

Tests on distribution transformers

An extensive test program was used to study the behaviour of transformers during electrical storms. The primary purpose of the tests was to subject the transformers to steep fronts, which corresponded to a voltage and current impulse with a rise time of less than 1.2 microseconds.

Tests on 25-kV metal-enclosed switchgear

A study was carried out on the performance of 25-kV metal-enclosed switchgear subjected to rigourous ambient conditions, especially high levels of humidity.

Mechanical and Thermomechanical Laboratory

The engineering activities and tests conducted at the mechanical and thermomechanical laboratory involve assessing and solving technological problems related to the mechanical and thermomechanical behaviour of transmission and distribution systems, as well as meeting industry needs. In 1997, the laboratory's activities were geared toward developing new test benches and equipment.

New test benches

Construction was completed and commissioning initiated on a new test bench, the only one of its kind in the world. The test facility will be used to assess the ageing of generator busbars and subject them to multiple stresses applied simultaneously. The aim of the project is to predict the residual life of in-service busbars. Laboratory personnel also completed the assembly of a new vibration test bench, which is expected to be commissioned in early 1998 and will be used to simultaneously apply a biaxial vibration and a climatic variable on the equipment being tested.

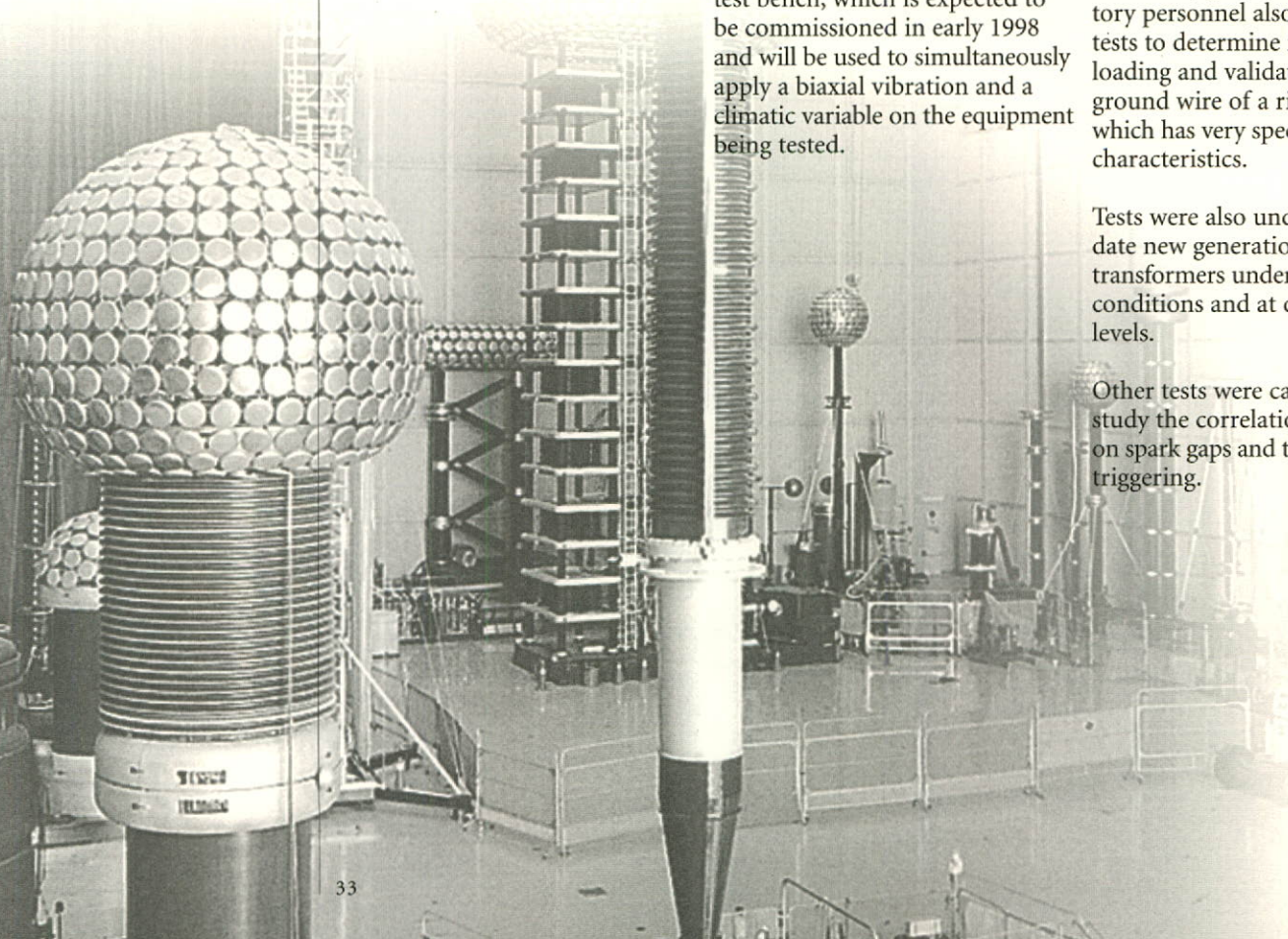
Main tests

As part of a project aimed at countering the effects of galloping on transmission lines, a galloping inducer was developed and a test program carried out on the laboratory's experimental line. The program consisted in analyzing the dynamic behaviour of conductors and bundle conductors, as well as the spacers (designed to counter the phenomenon), and suggesting improvements to increase their efficiency. The program will continue throughout this year.

For nearly a decade, Hydro-Québec has been systematically replacing the overhead ground wires on its transmission system with fibre-optic-equipped overhead ground wires. In order to qualify them, a number of failure, optical signal attenuation, short-circuit, compression, ageing, aeolian vibration and fatigue tests were carried out under laboratory conditions as well as on the experimental line and at the high-capacity traction test area (up to 800 kN). Laboratory personnel also conducted tests to determine maximum ice loading and validated the optical ground wire of a river crossing, which has very specific mechanical characteristics.

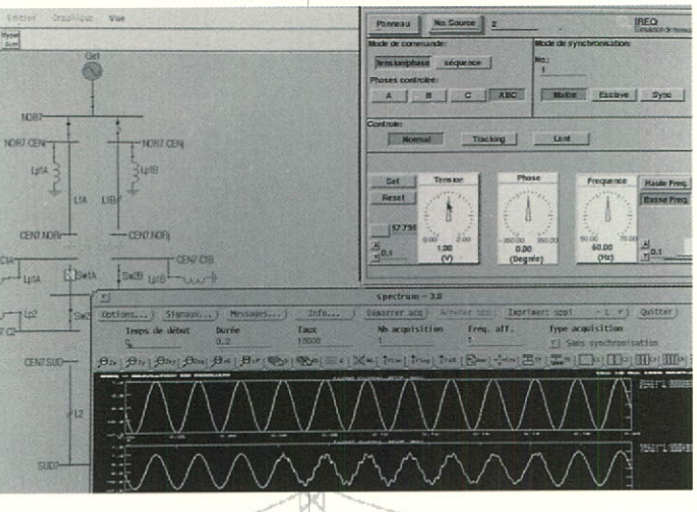
Tests were also undertaken to validate new generations of optical transformers under varied climatic conditions and at different voltage levels.

Other tests were carried out to study the correlation between ice on spark gaps and their unexpected triggering.



Development of new equipment

In addition to its various test programs, the laboratory also developed a system for detecting partial discharges generated on the overhead distribution system, a technology which should be upgraded and adapted to Hydro-Québec's underground distribution system in 1998.



To facilitate the installation of optical ground wires using the cradle-block method, laboratory personnel developed an independent tractor for pulling the lead lines, thus eliminating restrictions for the protection of roadways located under the lines and shortening the time of the operation. This technology may be upgraded and used for other applications.

Power System Simulation Laboratory

The power system simulation laboratory was set up to study the behaviour of large power systems using the latest analog and digital technologies. These high-tech tools are used to analyze the phenomena observed on the transmission and distribution systems under varied conditions, and then validate the respective automatic, control and protection systems. Ushering in an era of real-time digital simulation, the past year led to the development of a new distribution system test area.

Commissioning of the all-digital simulator

The new technology – known as Hypersim – is designed to model a medium-size transmission system and interface it with control systems hardware (e.g. protection relays, converter controls). It has all the capabilities of the hybrid simulator plus the benefits of decreased simulation setup and network validation time.

The first study using the all-digital simulator involved a solid-state transfer switch. A technology transfer was done by Teqsim, the Hydro-Québec subsidiary which is marketing the new simulator and has already sold one unit to the Japanese firm Hitachi for a study on direct-current control systems.

New distribution system test area

A new test area consisting of a distribution system reproduced on the all-digital simulator will be used for conducting tests on the solid-state transfer switch as well as for a study on power quality. The test area comprises several models of distribution system components as well as models of industrial and residential loads (e.g. induction motor, random-switching resistive loads, arc furnace, non-linear lighting loads). These models were developed during the course of a project conducted on behalf of the *direction Clientèle d'affaires et Mesurage.*

Main tests

The laboratory tested a universal power-flow controller for American Electric Power (AEP), which intends to install it on its own power system. The tests conducted on the system, which is part of the FACTS (Flexible AC Transmission System) family of controllers, focused on its interactions with the 138-kV, 345-kV and 765-kV transmission systems.

The laboratory completed phase 4 of a study on control systems for the multiterminal DC link under operating conditions. Initiated in 1995, the aim of this huge project was to check the performance, behaviour and response of these systems based on integration on the power system of series compensation and new substations and generating stations.

Tests conducted for the Vermont-based firm Green Mountain simulated the commissioning of an apparatus designed to regulate power quality and located the source of problems observed on the capacitor banks of the client's wind farm.

Field-Testing Unit

After integrating the field-testing unit in 1997, Hydro-Québec's laboratories (unité Laboratoires) can offer a full range of in situ and laboratory tests as the new unit is designed to carry out tests and measurements on every scale for clients worldwide. This year, the field-testing unit's activities revolved around the diagnosis, performance analysis, equipment safety and acceptance requirements of new facilities.

Main tests

The field-testing unit developed and validated a method for measuring the impedance at one point of the 25-kV network. This report led to the acquisition and demonstration of a load switched by IGBT (insulated-gate bipolar transistor). The method will be applied to TransÉnergie's 120-kV network in 1998.

At TransÉnergie's request, a technique for measuring harmonic and transient voltages was developed and validated. Tests confirmed the possibility of using this type of measurement for capacitor voltage transformers, which are normally used for measurements at 60 Hz.

The field-testing unit conducted special tests to determine the sturdiness of certain elements of network series compensation following a request made by the Facilities Group (*groupe Équipement*). Dielectric characterization of a group of varistors was done on site using the partial-discharge method, thanks to the combined efforts of the field-testing unit and mechanical and thermo-mechanical laboratory personnel.

On behalf of Hydro-Québec's Distribution and Customer Services group and in conjunction with IREQ's apparatus group (*unité Appareillage*), a technique for measuring touch voltages was developed and validated under actual operating conditions. The new technique is used for tests conducted on the premises of residential, commercial and industrial clients.

Diagnostic tests were carried out and corrective measures recommended after lightning damaged the distribution system in a residential area of Quebec City. This work required the development of a miniaturized lightning surge generator.

Electromagnetic compatibility studies were carried out on the premises of industrial clients who were experiencing production shutdowns in order to analyze power system disturbances and the behaviour of protection systems. Corrective measures were then recommended.

The field-testing unit put its expertise to use for a project conducted by Hydro-Québec International on behalf of an electric utility in the Phillipines. The project consisted in implementing an HVDC transmission system and of providing on-site technical support.

Lastly, a U.S. manufacturer asked the field-testing unit to carry out a series of diagnostic tests for the implementation of a new technology related to the quality of the electrical supply.

Calibration Laboratory and Equipment Repair

Some time ago, the calibration laboratory obtained CAN-P-4C and ISO Guide 25 accreditation, recognition which in 1997 prompted it to extend its services to all of Hydro-Québec's business units and outside clients who need reliable and precise measuring devices (e.g. voltmeters, ammeters, wattmeters, voltage and current transformers, resistors, multi-purpose calibrators, high-precision multimeters, etc.).

Until then, the laboratory had been basically reporting to the *direction Recherche et Développement*, but this past year it reaped the benefits of its promotional efforts. As a result, it has calibrated several measuring devices of clients such as Hydro-Québec, Pratt & Whitney, Alcan's research centre in Jonquière, and Ontario-based RCC Electronic, which markets Hydro-Québec's programmable calibrator.

The laboratory has the expertise needed to verify and repair all types of measuring devices required for power system operation and testing. Lastly, an accreditation application was submitted for temperature measurements, which will no doubt help the laboratory pass another milestone in its development.

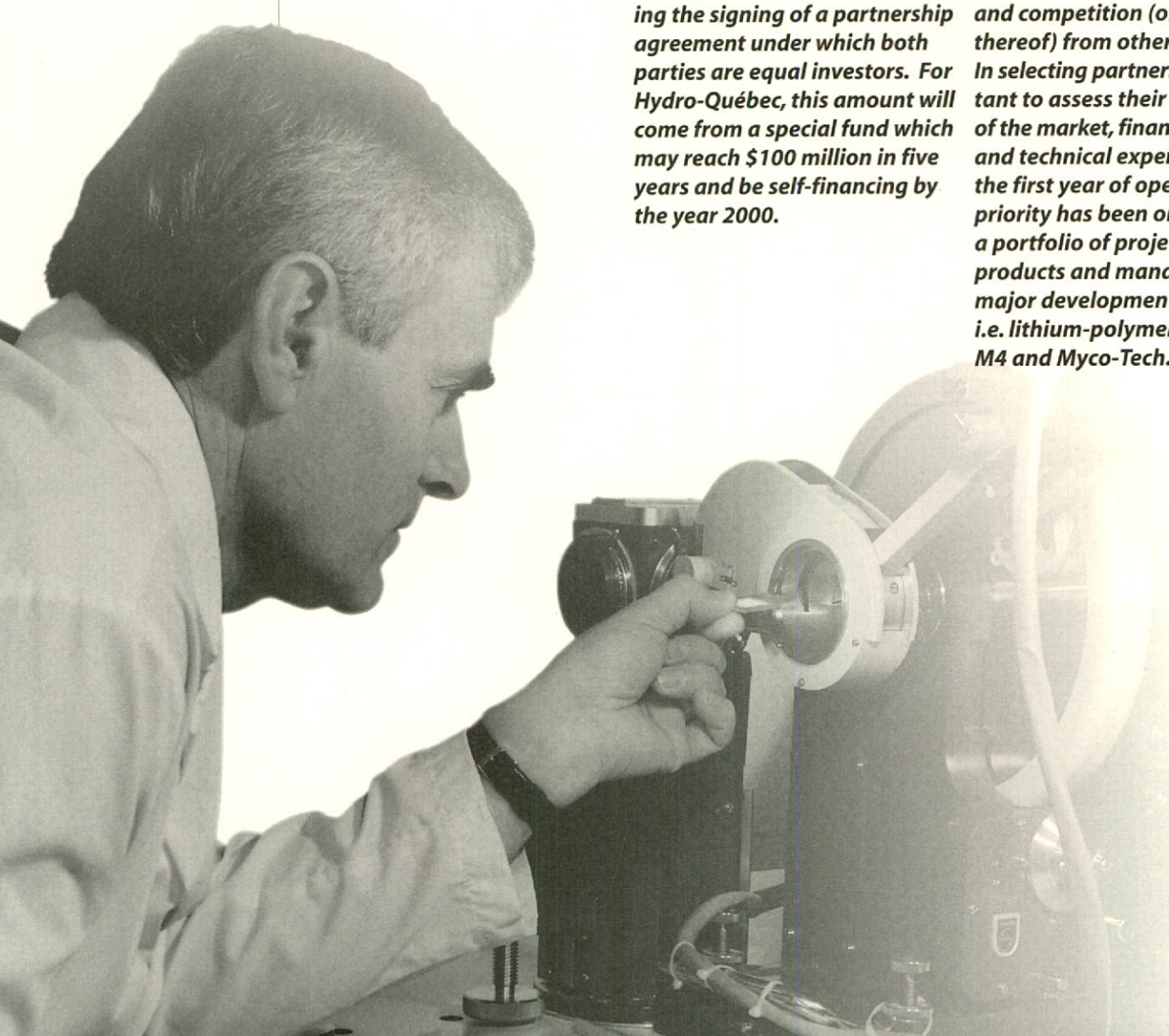
Product Development

The new Product Development directorate* (direction Développement de produits) *was set up in 1997 to hone Hydro-Québec's competitive edge in the new knowledge-based economy by overseeing the development of commercial products resulting from various projects and programs, preferrably those carried out as joint ventures. Its mandate is to act as a link between the laboratory and the market, meaning that it must take all the necessary steps to ensure that once a product's design and prototypes have been validated, it is then ready to be put on the market.

In other words, the new department is neither research-oriented – it does not invest any funds – nor involved in marketing or setting up subsidiaries and affiliates. Rather, it provides a link between the laboratory and the market by selecting projects with high commercial potential, setting up the projects retained, and managing related activities with a view to delivering the products to the marketers. It thus carries out evaluations, studies and analyses on a product's intellectual property, its competitive advantages, the scope of the market, the optimization of the specifications to increase their value, etc. Once the project has been selected, the department takes preliminary steps regarding the signing of a partnership agreement under which both parties are equal investors. For Hydro-Québec, this amount will come from a special fund which may reach $100 million in five years and be self-financing by the year 2000.

The department's organizational structure and operating procedures are premised on a matrix-management approach, which makes full use of the resources and know-how of the utility and its partners. The same project manager oversees all aspects of a project related to a given product, as well as the team of researchers and specialists responsible for the product's final development.

Since this is a new area of activity, management methods and procedures for selecting projects and partners first had to be established. Potential projects are evaluated according to a rigorous screening process related to commercial viability, competitive edge for the user, and competition (or the lack thereof) from other products. In selecting partners, it is important to assess their knowledge of the market, financial stability, and technical expertise. During the first year of operation the priority has been on setting up a portfolio of projects and products and managing three major development projects, i.e. lithium-polymer batteries, M4 and Myco-Tech.



Less than one year after it was set up, the Product Development department has already met a number of its objectives. By late 1997, its project and product portfolio already included several signed agreements involving investments of over $15 million from the partners' end. These agreements covered a wide range of fields, as described below.

Agreement with Syprotec on an acoustic detection system

The agreement signed with Syprotec, a firm based in Pointe-Claire, Québec which specializes in transformer monitoring, concerns the development of an acoustic fault detection system for old and new transformer tap changers. The new system processes and records acoustic signals emitted during tap changer operation and then compares the data to subsequent recordings in order to detect potential problems.

The acoustic detection system was developed by a team of IREQ specialists on behalf of TransÉnergie. The agreement involves investments totalling $700,000.

Partnership agreement with Snemo regarding the Moniteq system

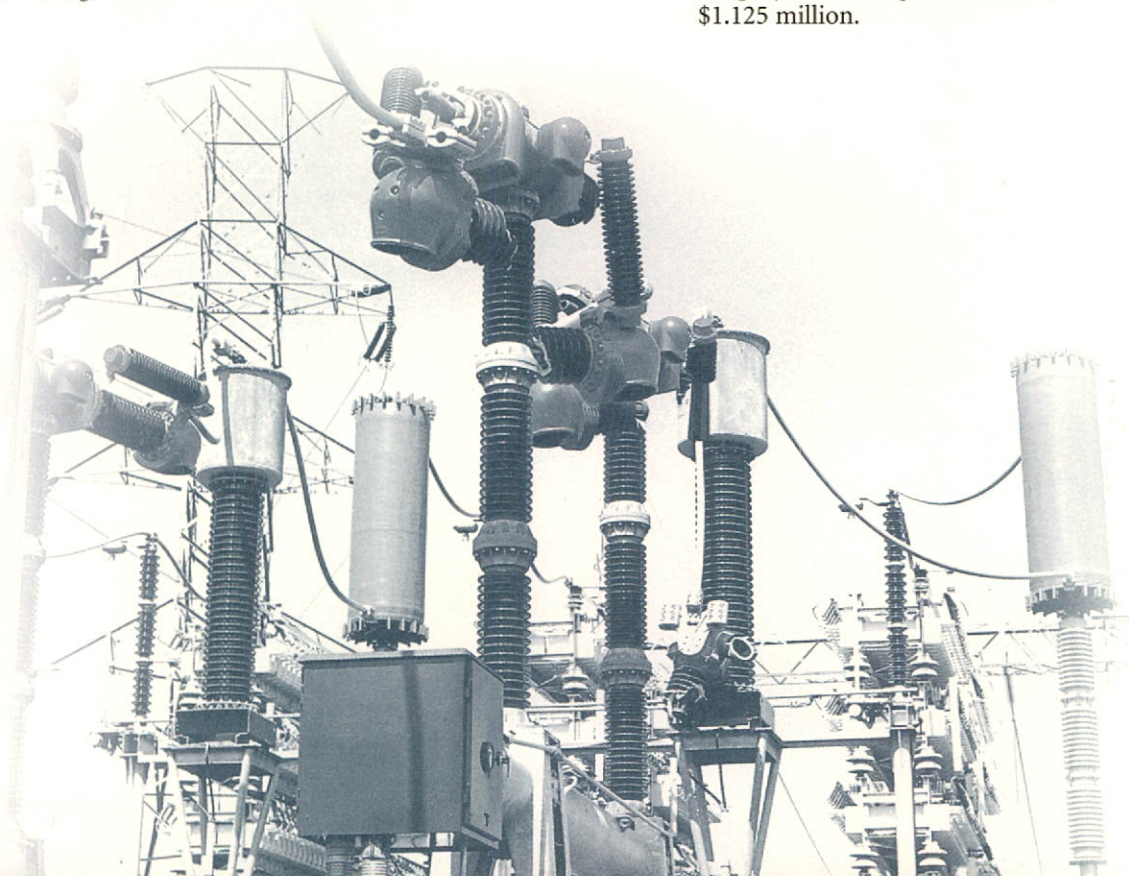
A partnership agreement has been concluded with Snemo, a firm based in Brossard, Quebec, which specializes in control and monitoring systems for power system equipment. The aim is to develop a commercial version of the Moniteq system, a device which ensures continuous monitoring of circuit breakers in substations and provides data on electrical and mechanical properties, while ensuring customized rather than periodic maintenance. Moniteq was initially developed by a team of researchers from IREQ's electrical apparatus division on behalf of TransÉnergie.

The commercial version of Moniteq targets a market of some 3,000 PK and PKV-type circuit breakers, one third of which have been installed on Hydro-Québec's transmission system. The two partners have invested some $1.8 million to date.

Agreement with Soulé-Bardin on a system for the remote signalling of fault indicators

The French electrical equipment manufacturer Soulé-Bardin is a partner in a project aimed at developing a system for the remote signalling of fault indicators. Designed to improve the power-service continuity index of distribution substations, the system is used to remotely transfer data on the state of each indicator as well as the approximate values of the instantaneous current flowing in each phase. In the case of a fault, the system identifies the defective line and detects the problem, thereby reducing response time and, consequently, the duration of power outages. The system is also useful for distribution system load management.

The system was developed by IREQ's electrical apparatus department (*unité Appareillage électrique*) on behalf of the *direction Conduite des réseaux de distribution*. The agreement generated some $400,000 in 1997, and negotiations are under way regarding financing for the final phase of the project totalling an estimated $1.125 million.



Agreement with Prolab on a process used to manufacture azelaic acid

The partnership agreement signed with Prolab, a firm based in Black Lake, Québec which specializes in the manufacture of oils and lubricants, is aimed at developing an industrial process for manufacturing azelaic acid, a component of such products as adhesives, plasticizers and lubricants. In an effort to reduce the high cost of current processes, the *unité Procédés électrochimiques et métallurgiques* at LTEE designed a much more economical process based on a chemical reaction.

Backed by investments totalling $4.12 million, the agreement could lead to the construction of an azelaic acid manufacturing plant if the results prove to be conclusive. About a dozen other projects under study would require investments of several million dollars from potential partners.

Industrial phase of the lithium-polymer battery (LPB) project

The year 1997 marked the start of the industrial phase of the lithium-polymer battery (LPB) project aimed at developing all-solid lithium-polymer batteries for electric vehicles (cars and small off-highway motor vehicles), for activities requiring storage batteries (such as telecommunications), and for use in electronics.

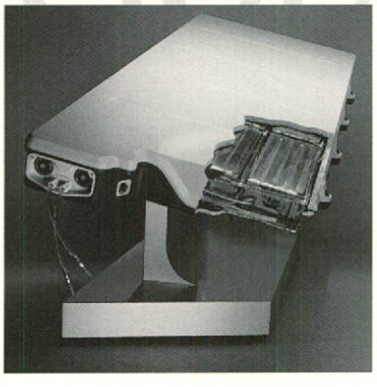
With the completion of Phase II of the project, major milestones have been passed in the development of this state-of-the-art technology: demonstration of the module and battery technology; assembly and startup of 13 modules of 2 kWh; and grouping of four of these modules into a first battery pack.

Phase III has already been covered under a new agreement between Hydro-Québec and its partners and the United States Advanced Battery Consortium (USABC). The objective of this phase is to decrease manufacturing costs and meet the performance objectives set by USABC with a view to marketing the next generation of batteries for electric vehicles (EVs). Spanning two years, the third phase, valued at US$24.5 million, brings total investments in the LPB project to US$84.3 million. This series of contracts is the largest ever awarded by the U.S. consortium.

To equip the electric vehicles used for the road tests with batteries, Argo-Tech Productions, a wholly owned Hydro-Québec subsidiary, expanded the Boucherville pilot plant where the battery prototypes are manufactured. Starting in the summer of 1998, these investments totalling $8.5 million will allow the plant to increase its annual production to roughly 50 battery packs of about 30 kWh each. This work will also serve to demonstrate the manufacturing processes on a larger scale and determine production costs, data which will be very useful in implementing the first commercial EV-battery plant. Lastly, Hydro-Québec and 3M jointly presented the main features of the LPB technology at the International Electric Vehicle Symposium (EVS-14) held last December in Orlando, Florida.

Pre-industrial prototype of the M4 motor-wheel

The M4 motor-wheel project, which consists of an innovative power train comprising four motor-wheels, should soon lead to the development of a pre-industrial prototype. In June 1997, Hydro-Québec introduced a new generation of motor-wheel, which can be seen as a fully integrated model. In addition to the actual motor, the third-generation prototype comprises a power converter which conditions the energy supplied by the vehicle's batteries according to instructions transmitted by the driver to the motor wheel. The wheel contains the electronic controllers, which are the brain of the system, and the front-end motor-wheels are equipped with a cooling system.



Two integrated motor-wheel prototypes successfully passed intensive road tests. Conducted at the Laboratoires PMG Technologies in Blainville, Québec, the tests reproduced a 1000-km road trip which included varied conditions such as heavy traffic, highway driving, brief and extended descents and climbs on both steep and normal inclines, and a drive down a mountain road lasting five and a half hours.

A committee of experts appointed by Hydro-Québec submitted a report in August 1997 which confirmed the technological and commercial feasibility of the M4 project, drew up the target industrial and financial scenarios, and defined the best type of partnership for stepping up the development of a pre-industrial prototype. After reviewing the report, Hydro-Québec signed an agreement with three partners – SOFTINOV, owned by the Caisse de dépôt du Québec, the Fonds de solidarité of the FTQ, and SGF – backed by investments totalling $6 million for 1998 in a joint venture which will be responsible for continuing the technical and commercial activities related to the M4 motor-wheel.

In addition to an active search for partners in the automobile industry, work will be started on a new technical program aimed at developing three prototypes with different performance levels in order to provide the automobile industry with a greater variety of motor-wheels. Major development work will also be aimed at increasing the impact resistance, reliability and durability of the integrated motor-wheel.

Development of an organic herbicide for inhibiting the growth of vegetation

Hydro-Québec's transmission and distribution lines extend over 160,000 hectares. To provide access to these installations, which are often located in very remote wooded or mountainous areas, rights-of-way must be rigorously maintained to ensure the safety of workers. The current method combines the use of chemicals with mechanical cutting in certain predetermined locations. The cost of maintaining rights-of-way ranges from $5 to $7 million a year.

In an effort to improve the efficiency of maintenance procedures while increasing environmental protection, Hydro-Québec asked Université Laval to study organic agents likely to naturally inhibit stool shoot growth. The research findings led the utility to set up a multidisciplinary team to develop a new product, known as Myco-Tech, as part of a $2.5-million project carried out for the TransÉnergie division.

Myco-Tech is an indigenous fungus which has been integrated into an all-natural protective matrix which inhibits or devitalizes the growth of vegetation. This innovative organic method is a more efficient and cost-effective solution for dealing with the rapid growth of deciduous trees while protecting wildlife and the environment.

It was during Phase II of the project, begun in late 1996, that the best indigenous agent was found among the 300 strains tested. However, as the fungus used in Myco-Tech is found in nature, other tests had to be carried out to ensure that use of the product did not present a risk of uncontrolled growth. The tests involved characterizing the fungus' DNA and conducting in situ analyses using molecular probes. The tests also served to ensure that the fungus would survive and thrive in the field.

The next stage consisted in developing the product and its manufacturing process which already allows, at the present experimental stage, mastery of the manufacturing steps and control of its quality. The method of application, for its part, consists in simultaneously using mechanical cutting and spraying with a prototypical device which still needs to be optimized. This method has several advantages over the former one, which involved sequential operations. Hence, under both laboratory and in situ conditions, Myco-Tech was effective in devitalizing the stool shoots of deciduous trees and helped maintain the area's biodiversity without the disadvantages of conventional methods.

In addition to the above project, Hydro-Québec signed an agreement with the *Instituto Costarricense de Electricidad* of Costa Rica regarding the transfer of technology aimed at developing an organic herbicide for inhibiting the growth of vegetation in tropical climates. The commercial agreement for this project, valued at US$3.2 million, was signed in June 1997. An application for Myco-Tech certification is expected to be submitted in 1998 for both Canada and the United States. Efforts will also be made to optimize the manufacturing process and application method. Lastly, the project team is hoping to set up a joint venture for the final development and commercialization of the product.

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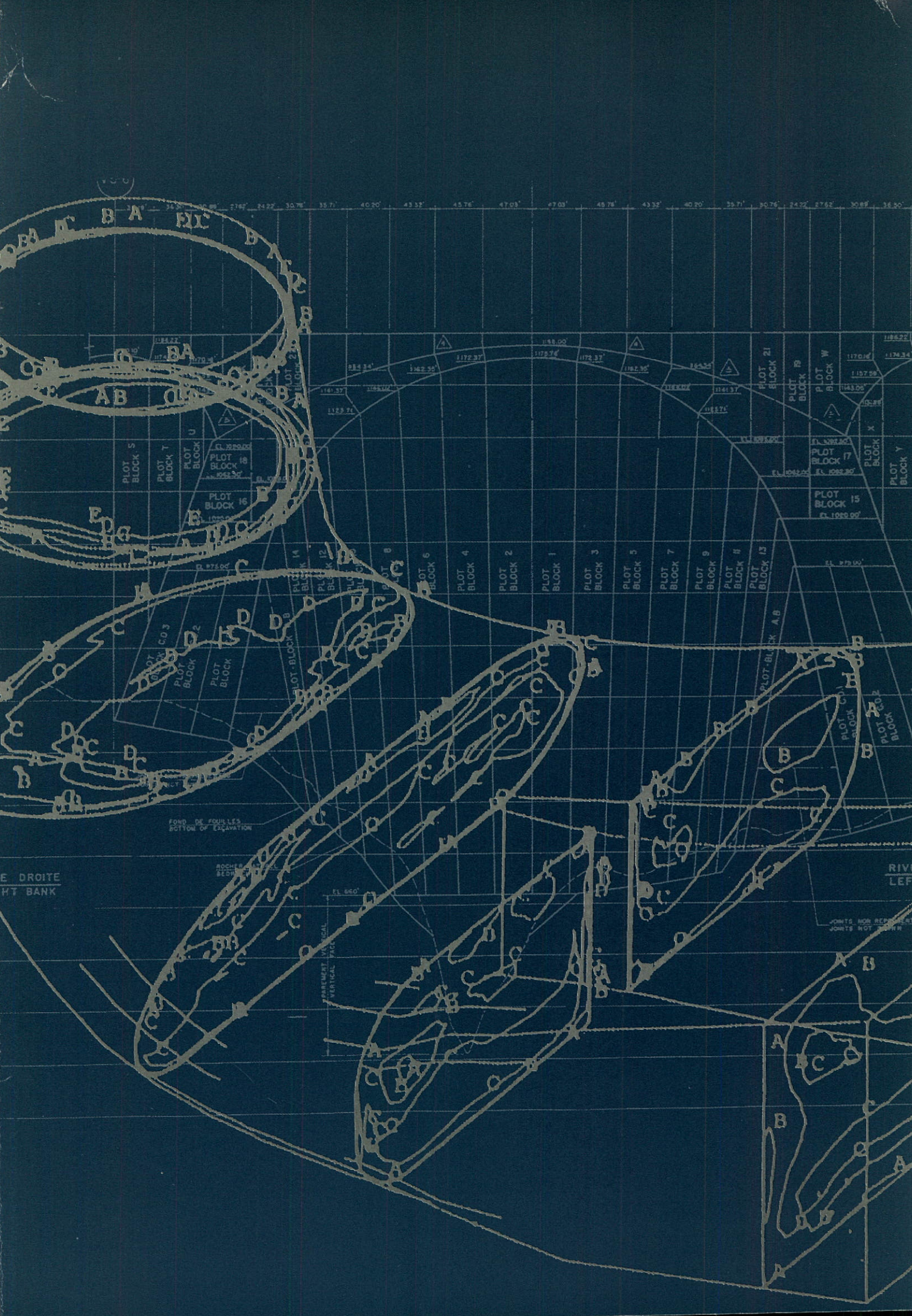
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